

NANOTECHNOLOGY EDUCATION

HEARING BEFORE THE SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

ONE HUNDRED TENTH CONGRESS

FIRST SESSION

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NANOTECHNOLOGY EDUCATION

TUESDAY, OCTOBER 2, 2007

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND SCIENCE EDUCATION,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 2:00 p.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Baird [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

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COMMITTEE ON SCIENCE AND TECHNOLOGY

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Subcommittee on Research and Science Education

Hearing on:

Nanotechnology Education

2318 Rayburn House Office Building
Washington D.C.

October 2, 2007
2:00 p.m. – 4:00 p.m.
2318 Rayburn House Office Building

WITNESS LIST

Dr. David Ucko
Deputy Division Director
Education and Human Resources Division on Research and Learning
National Science Foundation

Dr. Nivedita Ganguly
Head of the Science Department
Oak Ridge High School, Oak Ridge Tennessee

Dr. Hamish Fraser
Ohio Regents Eminent Scholar and Professor
Department of Materials Science Engineering
Ohio State University

Dr. Ray Vandiver
Vice President of New Project Development
Oregon Museum of Science and Industry

Mr. Sean Murdock
Executive Director
NanoBusiness Alliance

Dr. Gerald Wheeler
Executive Director
National Science Teachers Association

HEARING CHARTER

**SUBCOMMITTEE ON RESEARCH AND SCIENCE
EDUCATION
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES**

Nanotechnology Education

TUESDAY, OCTOBER 2, 2007
2:00 P.M.—4:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

1. Purpose

The purpose of this hearing is for the Subcommittee to receive testimony on H.R. 2436, the *Nanotechnology in Schools Act*, and also to review current nanotechnology education activities supported under the National Nanotechnology Initiative and to explore issues associated with educating students and the public about nanotechnology.

2. Witnesses

Dr. David Ucko, National Science Foundation, Deputy Division Director of the Education and Human Resources Division on Research and Learning. Dr. Ucko coordinates education activities in nanoscale science and engineering across NSF.

Dr. Nivedita Ganguly, Head of the Science Department at Oak Ridge High School, Oak Ridge Tennessee.

Dr. Hamish Fraser, Ohio Regents Eminent Scholar and Professor, Department of Materials Science Engineering, the Ohio State University.

Dr. Ray Vandiver, Vice President of New Project Development, Oregon Museum of Science and Industry.

Mr. Sean Murdock, Executive Director, NanoBusiness Alliance.

Dr. Gerald Wheeler, Executive Director, National Science Teachers Association.

3. Overarching Questions

- What unique benefits does access to high-tech equipment generally offer to high school students, undergraduates and community college students, and visitors to informal science centers?
- What science, technology, engineering, and mathematics (STEM) education goals do hands-on opportunities with high-tech equipment fulfill at the secondary school level and at the post-secondary school level? What goals does providing these opportunities meet for the nanotechnology research and business communities?
- What factors need to be considered when bringing high-tech equipment to the classroom?
- What types of educational activities is the Federal Government funding in nanoscale science and engineering under the National Nanotechnology Initiative? Is the level of resources available for these activities adequate? Are the priorities for funding appropriate?

4. Background*Nanoscale Science and Engineering*

The emerging field of nanoscale science and engineering (NSSE)—the science of manipulating matter at the molecular level—holds tremendous potential. Research in this area has already led to medicine-dispensing contact lenses, stain-resistant clothing, and many other advances in science, health, and consumer products. The impact of this technology on Americans' quality of life and economic prosperity could be enormous and thus it is clearly necessary for the United States to stay at the forefront of scientific research and development in the NSSE field. To accomplish

this, the Nation needs a full pipeline of talented engineers and scientists, and a scientifically literate public, able to exploit and understand this new science.

H.R. 2436, the Nanotechnology in Schools Act

The purpose of H.R. 2436, the *Nanotechnology in Schools Act*, is to expose American students to the high-tech realm of nanotechnology, leading them to a greater interest and higher facility in science and technology. The bill would direct the National Science Foundation to create a grant program making it possible for eligible institutions to purchase nanotechnology equipment for educational purposes. The qualifying institutions—high schools, two-year colleges, undergraduate serving programs, and informal science education centers—could apply for competitively awarded, merit-based grants of up to \$150,000 to purchase instrumentation and materials to teach NSSE principles to students and/or the public. In addition to equipment, the funds could be used for relevant software, as well as teacher and faculty professional development, and student educational activities. In making their awards, NSF is encouraged to select institutions that represent a diverse geographic area and a diverse student body. The activities in H.R. 2436 are authorized at \$15,000,000 for fiscal year 2008, and for such sums as may be necessary for fiscal years 2009 through 2011.

Current Nanotechnology Education Activities Under the National Nanotechnology Initiative

The National Nanotechnology Initiative (NNI) has funded more than \$6918.1 million in research and related activities in NSSE across the federal science agencies since it began in 2001. In fiscal year 2007, Congress funded research in this area at \$1353.9 million. As part of its work on this initiative, NSF supports a number of educational activities designed to teach K–16 students, science teachers, faculty members, and the general public about nanotechnology. In fiscal year 2006, NSF funded \$26.2 million in this area and the agency reports similar funding levels for nano education for this year and next.¹ NSF estimates they educate 10,000 students and teachers per year with these funds. Major NSSE education initiatives include the National Center for Learning and Teaching (NCLT) in Nanoscale Science and Engineering and the Nanoscale Informal Science Education (NISE) Network. NCLT is a consortium of five universities with a mission to foster the Nation's talent in NSSE by developing methods for learning and teaching through inquiry and design of nanoscale materials and applications. They perform research and serve as a clearinghouse for information regarding NSSE curriculum, teaching methodologies, and professional development for the undergraduate and K–12 levels. NCLT is operating in the fourth year of a five year \$15,000,000 million grant. The NISE network received a \$12.4 million dollar grant from NSF in 2005 to develop methods of introducing the nanotechnology to the public and to draw students to careers in NSSE.

NSF also has a Nanotechnology Undergraduate Education Program which funded \$42.7 million since 2003. The grants in this program have gone to develop curriculum and purchase equipment in NSSE for undergraduate students in different science and engineering disciplines. As part of the Advanced Technology Education Centers program, NSF has funded \$2.68 million since 2004 to develop nanotechnology related technician education programs at community colleges.

Important Considerations

The vital role NSSE will play in the future of science and technology dictates the necessity of supporting educational activities that will cultivate students who are enthusiastic and able to pursue careers in all aspects of nanotechnology. However, to maximize the benefit the opportunity to work with high-tech scientific equipment can have for students, the new technology and concepts must be carefully integrated with the larger body of science knowledge students must already learn. Professional development for anyone teaching new technology should also be considered an essential part of bringing high-tech scientific equipment to the classroom. NSF's current and future NSSE educational activities offer the chance to create holistic programs that will increase the depth and breadth of student's science knowledge.

¹ FY 2007 estimate: \$27.8 million; FY 2008 budget: \$28.6 million.

5. Questions to Witnesses

Dr. David Ucko

1. Please describe NSF's current activities in nanoscale K–16 science education and the funding level for these activities. Why does NSF believe funding and promoting nanoscale science and engineering educational activities is important? How does nanoscale science and engineering education fit into the larger picture of improving STEM education and literacy in all levels of the population?
2. What educational activities (and which audiences) does NSF believe are most important to reach with information on nanoscale science and engineering?
3. At all levels, but the K–12 and informal science education level especially, is professional development and the integration of this new, advanced field into existing curriculum, receiving adequate attention and forethought?
4. What is NSF's opinion on H.R. 2436, the *Nanotechnology in Schools Act*? Would this program complement the Foundation's current activities in nanoscale science education?

Dr. Nivedita Ganguly

1. Please describe your experiences using high-tech scientific equipment in the high school classroom. What benefits do you feel students would receive from having the opportunity to work with nanotechnology equipment? Would students from a wide variety of backgrounds be able to use and learn from the equipment?
2. With the myriad topics high school science teachers must currently cover, how do educators strategically choose new experiences for students in the sciences? How do you integrate the newest concepts into the curricula to give students an appreciation for the new material and an excitement about science, as well as a deeper understanding of the fundamentals?
3. What kinds of professional development opportunities would teachers need to help them integrate nanotechnology into their curriculum and properly use and maintain high-tech equipment?
4. Are there problems obtaining funds needed for the maintenance of high-tech equipment? How does Oak Ridge High School address these?

Dr. Hamish Fraser

1. Please describe current nanotechnology education efforts at the undergraduate level. As new fields emerge in science, how do university science departments merge them into the current undergraduate curriculum?
2. How would a grant program, like the one proposed by H.R. 2436, be used by undergraduate serving programs? At the college level, does the opportunity to work with new technology draw in students who might otherwise have been uninterested in science? Do hands-on experiences offer a unique learning opportunity that is difficult to replicate in a lecture?
3. What types of nanotechnology equipment could be used for educational benefit at the undergraduate level?

Dr. Ray Vandiver

1. Please describe the nanoscale science and engineering educational activities the Oregon Museum of Science and Industry (OMSI) is engaged in and OMSI's role in the Nanoscale Informal Science Education Network.
2. Would H.R. 2436, the *Nanotechnology in the Schools Act*, be a beneficial resource for informal science education institutions? What priority should it be given relative to other kinds of support for informal science education activities? How would science museums integrate advanced equipment into their educational activities?
3. What types of professional development opportunities are available to informal science educators? What types of programs would need to exist to ensure that these educators understand both the scientific concepts, as well as the equipment?
4. How do informal science education centers decide which subject matter they will focus on? What resources do they use to help create exhibits and pro-

gramming that matches content to the knowledge level and interest of the audience?

5. Do science museums have resources to maintain advanced equipment?

Mr. Sean Murdock

1. What challenges do nanotechnology oriented businesses currently face in filling their workforce needs? Are there particular skills that are in short supply?
2. What effects would the nano-business community hope to see from introducing students and the public to nano-science through hands-on experiences?
3. Are nano-oriented businesses currently engaging in educational activities? How can they be encouraged to form partnerships that will give students opportunities beyond the classroom where they can further explore and engage with nanotechnology?

Dr. Gerald Wheeler

1. What is the National Science Teachers Association's opinion on H.R. 2436, the *Nanotechnology in Schools Act*? What is the appropriate role for high-tech equipment in the secondary science classroom?
2. With the myriad topics high school science teachers must currently cover, how do educators strategically choose new experiences for students in the sciences? How do you integrate the newest concepts into the curricula to give students an appreciation for the new material and an excitement about science, as well as a deeper understanding of the fundamentals?
3. What kinds of professional development opportunities would teachers need to help them integrate new, high-tech equipment into their curriculum and properly use and maintain high-tech equipment?

Chairman BAIRD. Good afternoon. Welcome to our panelists and those in the audience and my good friend, Vern Ehlers. I want to welcome everyone to today's hearing on nanotechnology education and thank our witnesses for being here. This hearing stands adjourned. Little nano joke, very little.

Developments in the field of nanotechnology are incredibly exciting. Science now has the ability to not just see or perceive matter at its smallest scale but also to manipulate it and create new materials. I am certain the flood of discoveries and applications just around the corner will touch every aspect of our lives, including medicine and computing. Indeed, some of these applications, like enhanced textiles, have already arrived, generating billions of dollars in economic impact.

The questions we are concerned with today is how we will build the workforce to propel discovery and keep America at the forefront of nanotechnology. This question once again brings us to science education, which has been an issue of great concern for this committee.

At present, the Federal Government invests \$1.5 billion in nanotechnology research and development through the National Nanotechnology Initiative. Certainly, this investment is crucial. However, if we ignore the fact that there simply are not enough American students prepared to carry out this research and development, we could find much of that investment wasted as other countries take the lead in nanotechnology.

We face two very steep challenges in science education. One is to raise students' interest in math and science. The other is to raise their competency.

The *Nanotechnology in the Schools Act*, which I will let my friend, Congresswoman Hooley, from Oregon, explain in a moment in detail, will offer an intriguing way to attack both of these challenges.

I am interested in hearing from our witnesses today about how putting incredibly advanced technology into the hands of students can capture their attention and inspire them to pursue math and science career paths, especially in the area of nanotechnology.

I am also interested to hear about the investment the Federal Government is already making in nanotech education, both for students and the general public, and to learn more about the impact these investments are having.

I will now yield to my good friend, Congressman Ehlers, Dr. Ehlers, the Ranking Member of the Committee.

[The prepared statement of Chairman Baird follows:]

PREPARED STATEMENT OF CHAIRMAN BRIAN BAIRD

Good afternoon. I'd like to welcome everybody to today's hearing on *Nanotechnology Education* and thank our witnesses for being here.

Developments in the field of nanotechnology are incredibly exciting. Science now has the ability to not just see or perceive matter at its smallest scale, but also to manipulate it and create new materials. I am certain that the flood of discoveries and applications just around the corner will touch every aspect of our lives, including medicine and computing. Indeed, some of these applications, like enhanced textiles, have already arrived—generating billions of dollars in economic impact.

The question we are concerned with today is how we will build the workforce to propel discovery and keep America at the forefront of nanotechnology. This question

once again brings us to science education, which has been an issue of great concern for this committee.

At present, the Federal Government invests one and a half billion dollars in nanotechnology research and development through the National Nanotechnology Initiative. Certainly, this investment is crucial. However, if we ignore the fact that there simply are not enough American students prepared to carry out this research and development, we could find much of that investment wasted as other countries take the lead in nanotechnology.

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The *Nanotechnology in the Schools Act*, which I will let my friend from Oregon, Ms. Hooley, explain in detail, offers an intriguing way to attack both of these challenges.

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I am also very interested to hear today about the investment the Federal Government is already making in nanotechnology education, both for students and the general public, and the impact these investments are having.

Mr. EHLERS. I thank the Chairman and I appreciate his demonstration of his nano sense of humor. Sorry about that.

Chairman BAIRD. I had it, though. That is pretty good.

Mr. EHLERS. Actually, I am not sorry. Since you got it.

Thank you, Mr. Chairman. Today's hearing will examine a bill to prepare students for careers in nanotechnology and look at the current state of nanotechnology education at the high school and undergraduate level. The Science and Technology Committee has supported a number of nanotechnology and education activities through the National Nanotechnology Initiative and remains interested in ways that we can improve these programs. I am glad that we will hear today from a variety of individuals who all agree that nanotechnology is an important part of our future science and technology workforce.

It would be wonderful if every high school and college student had the opportunity to use nanotechnology equipment and become exposed to the cutting edge of this innovative field at an early age. The intent of the bill, to grow the nanotechnology workforce by capturing student interest early, is clearly commendable. With that said, though, I have some reservations as to the way that this bill attempts to achieve these goals.

Earlier this year the Research and Science Education Subcommittee examined another bill which authorized a pilot grant program at the National Science Foundation for high school laboratory equipment. The Partnership for Access to Library Science, Laboratory Science, better known as PALS, bill became a part of the *America COMPETES Act*, signed into law in August.

The schools eligible for the PALS grants have to be high-need schools, and I believe this is appropriate. When we were evaluating the PALS bill, this subcommittee heard, learned from another panel of witnesses that at many schools the need for even the most rudimentary laboratory materials was indeed high.

We also learned from witnesses that at times, federal science education programs do not adequately align with State science and math standards, making it difficult for well-intentioned materials to be utilized by a typical classroom school teacher.

That leads to my concerns about this bill, H.R. 2436, because it provides equipment for low-need schools. Perhaps a better route to

achieve the bill's goals would be to encourage companies to donate equipment and employee time to exceptional high schools and undergraduate programs. Perhaps even considering tax incentives for that program.

This committee's bipartisan goal has always been to ensure that all of our nation's students receive an excellent education in science and not just the low-need schools. And we will not waver from that goal. I hope that our witnesses today and help us determine how H.R. 2436 would help us achieve that goal so that all students benefit, not just those with exceptional teachers, students, and equipment.

I yield back.

[The prepared statement of Mr. Ehlers follows:]

PREPARED STATEMENT OF REPRESENTATIVE VERNON J. EHLERS

Today's hearing will examine a bill to prepare students for careers in nanotechnology, and look at the current state of nanotechnology education at the high school and undergraduate level. The Science and Technology Committee has supported a number of nanotechnology and education activities through the National Nanotechnology Initiative, and remains interested in ways that we can improve these programs. I am glad that we will hear today from a variety of individuals who all agree that nanotechnology is an important part of our future science and technology workforce.

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Chairman BAIRD. Thank you, Dr. Ehlers.

Ms. Hooley, I would now recognize the author of the bill, the gentlelady from Oregon, Darlene Hooley.

Ms. HOOLEY. Thank you, Mr. Chair. I appreciate you holding this hearing today, and I appreciate your interest in this.

Everyone in this room can agree that the emerging field of nanotechnology holds tremendous potential, potential that is becoming more and more evident with every new breakthrough. Research in this area has already led to new cancer treatments, more powerful computers, and energy conversion and storage breakthroughs.

Nanotechnology will revolutionize manufacturing, computing, energy, health care, national defense, and many other sectors by improving the way things are designed and made.

It is clearly necessary for the United States to remain at the forefront of research and development in the field of nanotechnology. Already we are facing challenges to our leadership by China, Japan, the European Union, India, and others.

For America to remain and expand its leadership, we must have a full pipeline of scientists and engineers who are capable of conducting nanotechnology research and development. And we must have a scientifically literate public, able to exploit and understand this new science.

The purpose of my legislation, the *Nanotechnology in the Schools Act*, is to expose American students to the high-tech realm of nanotechnology, encouraging them to take a greater interest in this new field.

It authorizes \$15 million for the National Science Foundation to create a grant program making it possible for high schools, two-year colleges, undergraduates serving institutions, and informal science education centers to purchase nanotechnology equipment for educational purposes.

These grants can be used to purchase instruments and materials to teach nanotechnology principles to students and the public. In addition, the funds can be used for training teachers and professors to use these tools in the classroom and the laboratory.

I want to thank all of our witnesses for agreeing to testify today and for providing your valuable insight into the best way that we can introduce nanotechnology to America's greatest asset: its students.

And with that I yield back the remainder of my time.

[The prepared statement of Ms. Hooley follows:]

PREPARED STATEMENT OF REPRESENTATIVE DARLENE HOOLEY

Thank you Mr. Chairman.

First, I would like to thank you for holding this hearing today and for your work on this issue.

Everyone in this room today can agree that the emerging field of nanotechnology holds tremendous potential, potential that is becoming more and more evident with every new breakthrough. Research in this area has already led to new cancer treatments, more powerful computers, and energy conversion and storage breakthroughs.

Nanotechnology will revolutionize manufacturing, computing, energy, health care, national defense, and many other sectors by improving the way things are designed and made.

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For America to maintain and expand its leadership, we must have a full pipeline of scientists and engineers who are capable of conducting nanotechnology research and development. And we must have a scientifically literate public, able to exploit and understand this new science.

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These grants can be used to purchase instrumentation and materials to teach nanotechnology principles to students and the public. In addition, the funds can be

used for training teachers and professors to use these tools in the classroom and the laboratory.

Thank you to all of our witnesses for agreeing to testify today and for providing your valuable insight into the best way that we introduce nanotechnology to America's greatest asset, its students.

Chairman BAIRD. Thank the gentlelady for her initiative of the legislation of her opening remarks.

We have also been joined by Dr. Jerry McNerney. If there are other Members who wish to submit additional opening statements, those statements will be added to the record at this point.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Thank you, Mr. Chairman. Nanotechnology research and business are important to Dallas and important to Texas.

The Texas Nanotechnology Initiative is holding an international convention this week in Dallas. The focus is to allow researchers, start-up companies, government officials and others to learn about the latest research developments in this field.

Of added benefit are the connections that will be made and the ideas that will be exchanged.

In Texas, the governor has established a venture capital-like entity that invests State funds into small businesses with promising nanotechnology concepts.

That interest, in conjunction with a strong college and university emphasis throughout Texas, has positioned our state as a leader in nanotechnology research and development.

Today's hearing will explore how the National Nanotechnology Initiative supports nanotech education activities and how H.R. 2436, the *Nanotechnology in the Schools Act*, will further contribute to improvements in nanotech educational activities.

The National Nanotechnology Initiative (NNI) is a federal research and development program established to coordinate the multi-agency efforts in nonsocial science, engineering, and technology.

Because of the promise of nanotechnology to improve lives and to contribute to economic growth, the Federal Government established the NNI to help make the United States a global leader in nanotechnology development.

The *Nanotechnology in the Schools Act*, introduced by my colleague from Oregon, Congresswoman Darlene Hooley, requires the Director of the National Science Foundation to establish a nanotechnology in the schools program.

The program would award grants to public or charter secondary schools offering advanced science courses and to institutions of higher education, for the purchase of nanotechnology equipment and software and the provision of nanotechnology education to students and teachers.

As the Committee on Science and Technology considers the legislation, we want to gain insight from the education and business communities about how to best leverage our investments to best prepare students to enter nanotechnology careers.

I would like to extend a warm welcome to today's witnesses. Thank you, Mr. Chairman. I yield back the balance of my time.

[The prepared statement of Mr. Lipinski follows:]

PREPARED STATEMENT OF REPRESENTATIVE DANIEL LIPINSKI

I am pleased that with this hearing today, we will continue the discussion of what I see as a potentially enormous field that could impact virtually every sector of the economy—nanotechnology.

The State of Illinois has a long history in nanotechnology and was ranked eighth in the Nation this year by *Small Times* magazine of leading nanotechnology states. The University of Illinois at Urbana-Champaign has taken a lead with its four centers dedicated to the study of nanotechnology. U of I's Micro and Nanotechnology Laboratory recently underwent an \$18 million expansion, making it one of the Nation's largest and most sophisticated university-based centers of its kind.

Northwestern University also has been at the forefront, taking advantage of this emerging, transformational technology that has allowed it to differentiate itself and be a leader in the field. In fact, NU is ranked fifth in the Nation on the topic of nanotechnology, helping to make Chicago a leader in the field. The Northwestern International Institute for Nanotechnology is the first center of its kind in the world.

Northwestern's nanotech research has received a total of \$350 million thus far from State and federal funding sources. This research has resulted in approximately 10 spin-off companies, which are conducting cutting edge research yielding stunning results. Earlier this year, NU scientists demonstrated regenerative nanomaterial that allowed paralyzed mice to regain the ability to walk about one and a half months after initial treatments. Human tests should begin in a few years, which could have significant implications for treating Parkinson's and Alzheimer's patients. Another company is developing nanoencryption technology to protect consumers from unsafe, counterfeit drugs.

These examples give us just a glimpse into the new and exciting places where nanotechnology can take us. Let me commend Ms. Hooley on her important bill that will help to expand our efforts in the field of STEM education and thank Chairman Gordon for his dedication to this important issue. I look forward to continuing this discussion in the months ahead as we work to reauthorize the National Nanotechnology Initiative next year.

Chairman BAIRD. And at this point I would like to introduce our witnesses. Dr. David Ucko of the National Science Foundation is Deputy Division Director of the Education and Human Resources Division of Research on Learning in Formal and Informal Settings. He is involved with educational activities in nano-scale science and engineering across NSF.

Dr. Nivedita Ganguly is the Head of the Science Department at Oak Ridge High School in Oak Ridge, Tennessee.

Dr. Hamish Fraser is the Ohio Regents Eminent Scholar and a Professor of Material Science at Ohio State University.

I will briefly skip Dr. Ray Vandiver in favor of letting Ms. Hooley introduce him, as he is from Portland, across the river from me. Welcome, Doctor.

Mr. Sean Murdock is the Executive Director of the NanoBusiness Alliance.

And Dr. Gerald Wheeler is the Executive Director of the National Science Teachers' Association.

Ms. Hooley, would you care to introduce Dr. Vandiver?

Ms. HOOLEY. Yes. It gives me great pleasure to introduce Dr. Vandiver. He is the Vice President of New Project Development for the Oregon Museum of Science and Industry, a wonderful place, by the way. He is a Principle Department Head responsible for development, design, fabrication, and maintenance of OMSI's public exhibitions and programs.

Dr. Vandiver received his Ph.D. in atomic and molecular physics from the University of Missouri-Rolla. He has been involved in informal science education for the past 17 years. He has been the recipient of several grant awards in the field of informal science education from the National Science Foundation and NASA. He has been invited to sit on numerous panels as a representative of the Science Museum field, including at NSF, the National Institute of Health, the National Academies Committee on Assessing Technological Literacy.

Thank you, Doctor, for being here today. I am looking forward to hearing your insights on this issue. Thank you. And welcome, by the way.

Chairman BAIRD. Our witnesses should know we have a five-minute opening statement period and followed by questions. As I mentioned to some earlier this is a friendly committee. We have good discussions, and by and large it is positive on a topic like this, especially. If you don't talk about global warming, we will have even less of an argument probably. Although thus far with the

Committee make-up, you would be in good shape. If a few other Members join us, we will have a more spirited rapport on that.

As Dr. Ehlers pioneered in this committee, if the yellow light goes on, you will have about a three-second warning, and then the chair will drop out from under you, and you will disappear, and we will not hear from you again.

So with that let me begin with Dr. David Ucko. Thank you all for being here.

STATEMENT OF DR. DAVID A. UCKO, DEPUTY DIVISION DIRECTOR, DIVISION OF RESEARCH ON LEARNING IN FORMAL AND INFORMAL SETTINGS; DIRECTORATE FOR EDUCATION AND HUMAN RESOURCES, NATIONAL SCIENCE FOUNDATION

Dr. UCKO. Chairman Baird, Ranking Member Ehlers, and distinguished Members of the Subcommittee, thank you for the opportunity to address you today about NSF education programs on nanoscale science and engineering.

NSF invests in a comprehensive set of programs in formal and informal education. This investment is important because nanotechnology is an emerging field expected to have significant economic workforce and societal impact. It fits into the larger picture of improving science and engineering education and literacy by engaging learners in current research and the ongoing process of discovery.

Nano education presents some challenges. The content is abstract, and new discoveries get made daily. It is not in the mainstream K–12 curriculum and adding new content to existing overcrowded curricula and state standards, assessments, and textbooks isn't easy. Educational research and evaluation are limited.

This context has guided NSF program development. In FY 2007, investment for nano education awards was \$28 million out of a total NNI investment of \$373 million. Like other education awards, they target nearly all audiences from young learners through adults, via a wide range of activities.

I would now like to highlight some examples. NSF awards develop and research instructional resources for students and teachers in grades 7 to 12 when students begin to consider careers. NSF has funded a flagship program to bridge formal education in nano research through the National Center for Learning and Teaching in Nano Scale Science and Engineering at Northwestern University and other partners. It is developing the next generation of leaders in nano teaching and learning and building capacity through work in learning research and development, nano concept research and development, higher education, professional development for high school teachers, and evaluation.

Other K–12 projects are creating classroom modules. They follow a rigorous methodology based on determining initial student knowledge, identifying appropriate nano concepts and learning goals, developing student assessments, carrying out pilot tests and revision, dissemination, and assessing student understanding. Although nanoscience is far from a major curriculum thread, these projects are developing and testing models that could pave the way.

Advances in nanotechnology research also provide new opportunities in post-secondary education. The most recent

Nanotechnology Undergraduate Education competition focused on engineering of devices and systems and on societal, ethical, economic, and environmental issues. Nearly half the recent awards included equipment, such as scanning or atomic force microscopes as part of courses, modules, or laboratory experiences.

NSF awards promote public engagement and understanding. The Nanoscale Informal Science Education Network at Boston's Museum of Science and collaborators, is linking science museums and nano research centers to develop exhibits, programs, public forums, and media for implementation at more than 100 partner sites. In addition to increasing public knowledge, these activities provide a new model and national infrastructure for connecting scientific research and informal education.

NSF also supports education and outreach programs through its Nanoscale Science and Engineering Centers. Since 2001, NSF has funded 17 such centers, along with two user facility networks and others that focus on nano. All conduct a wide variety of educational activities complementary to their scientific research.

In addition, many core programs throughout NSF support nano education. In Advanced Technological Education, for example, the Penn State Center for Nanotechnology Education and Utilization has generated associate degree programs in nano fabrication at 20 sites across the state, including every community college.

So far, two nano education workshops have been held to foster a community of practice among educators from these diverse projects. A third being planned will provide the opportunity to disseminate initial findings so that others can build on them. In addition, the workshop will help inform NSF as it considers further opportunities for investment. NSF will also be guided by a program evaluation that will analyze and synthesize project reports and study the impact of researcher-educator collaboration.

With regard to the *Nanotechnology in the Schools Act*, purchase of equipment, along with training, can assist learning and teaching. On the other hand, the many programs that NSF have been and will continue to carry out legislative intent. The Subcommittee perhaps could consider revisiting this issue after research and evaluation have generated further knowledge about which educational strategies prove most effective for different audiences.

I hope these comments provide some context for your deliberation, and I would be glad to answer questions.

[The prepared statement of Dr. Ucko follows:]

PREPARED STATEMENT OF DAVID A. UCKO

Chairman Baird, Ranking Member Ehlers, and distinguished Members of the Subcommittee, thank you for the opportunity to describe National Science Foundation (NSF) education programs based on nanoscale science, engineering, and technology.

The NSF invests in a comprehensive set of programs in formal and informal nanoscale science and engineering education (NSEE). Overall, these programs seek to address the "Learning" goal in the NSF FY 2006–2011 Strategic Plan (*Investing in America's Future*¹), which is to cultivate a world-class, broadly inclusive science and engineering workforce, and expand the scientific literacy of all citizens. In addition, the programs seek to increase understanding through research and evaluation of effective learning and teaching about nanoscience and technology. Thus, they also

¹National Science Foundation Investing in America's Future: Strategic Plan FY 2006–2011. <http://www.nsf.gov/strategicplan>; last accessed 09/24/2007.

address the “Discovery” goal to foster research that will advance the frontiers of knowledge. These investments contribute to the National Nanotechnology Initiative (NNI) Societal Dimensions Program Component Area subtopic: Education-related activities such as development of materials for K–12 schools, undergraduate programs, technical training, learning in informal settings, and public outreach (PCA 7²).

Background

The NSF investment in NSEE is important for several reasons. Nanotechnology is an emerging field with enormous potential economic impact and implications for preparing our future workforce. In addition, NSEE opens new prospects for teaching and learning science and technology. It is inherently inter-disciplinary, drawing from physics, chemistry, biology, engineering, and other fields. It focuses on a size range (one to 100 nanometers) intermediate between the atomic and macroscopic scale that heretofore has been less studied and taught, yet involves new materials exhibiting unique and useful properties. As a result, nanotechnology offers a nearly limitless range of interesting applications that will likely impact our lives and society. For this reason, an informed public is essential. NSEE fits into the larger picture of improving science and engineering education and literacy by providing a vehicle for engaging learners in current research and the ongoing process of discovery.

NSEE also presents challenges. The concept of scale, particularly outside the realm of our everyday experience, is difficult to grasp. Content drawn from nanoscale science and engineering (NSE) is abstract, complex, and involves quantum effects that are also challenging to understand. Like other areas of current science and technology, the body of knowledge constantly changes as new discoveries are made daily around the world. From an instructional standpoint, NSE content is not a part of the mainstream K–12 curriculum. Because they were developed a decade ago, the National Science Education Standards make no mention of NSE. Widely used and tested NSE curricula do not yet exist, and it is difficult to add new content to existing overcrowded curricula, State standards, assessments, and textbooks. There is limited educational research and evaluation about learning and teaching in this area.

This context has guided NSF program development in NSEE. The NSF investment for NSEE awards in FY 2007 was \$28 million, out of a total NSF NNI investment of \$373 million. The educational investments are made by the Directorate for Education and Human Resources, of which I am part, as well as by the Directorates for Research and Related Activities. Like other NSF education programs, the NSEE programs seek to target nearly all audiences, from young learners to older adults, through a wide range of educational activities. They 1) develop and research instructional resources for students in grades 7–12 and their teachers; 2) develop and research undergraduate NSE programs; 3) promote public engagement and understanding through museum exhibits, programs, media, and web sites; 4) offer education and outreach programs in conjunction with NSE research centers; 5) incorporate NSEE within core programs, such as those that provide research experiences to teachers and students; and 6) study the impact of these educational efforts through research and evaluation. Awards are made based on proposals submitted to NSF and recommended through the merit review process.

I would like to highlight examples that demonstrate the range of audiences and activities addressed through these educational investments.

K–12 Nanoscale Science and Engineering Education

Students in grades 7 to 12 are a key audience for introducing NSEE because many are beginning to consider future careers. NSF has funded a flagship program to bridge formal education and NSE research through the *National Center for Learning and Teaching in Nanoscale Science and Engineering* (NCLT) at Northwestern University, in partnership with Purdue University, University of Michigan, University of Illinois at Chicago, and University of Illinois at Urbana-Champaign (with collaborating partners Alabama A&M University, Argonne National Laboratory, Fisk University, Hampton University, Morehouse College, University of Texas at El Paso, and several public school systems). The mission of NCLT is to develop the next generation of leaders in NSE teaching and learning, with an emphasis on capacity building. The work is organized around five themes: Learning Research and Development—developing, testing, and disseminating learning activities; Nanoconcept Research and Development—introducing the latest concepts into

²The National Nanotechnology Initiative: Research and Development Leading to a Revolution in Technology and Industry. Supplement to the President’s 2007 Budget. July 2006. p. 25. <http://www.nano.gov/NNI-07Budget.pdf>; last accessed 09/24/2007.

science and engineering courses; Higher Education—training faculty and developing undergraduate courses and programs; Professional Development for High School Teachers—training teachers in nanoscience/engineering concepts; and Evaluation. Additional information can be found at <http://www.nclt.us>.

Other NSEE K–12 projects are developing materials for classroom learning and teaching. *NanoLeap* (Mid-Continent Regional Educational Laboratory) is creating and testing two month-long units in nanoscience to be used as replacement units in high school physics and chemistry courses (see <http://www.mcrel.org/NanoLeap/>). *NanoSense* (SRI International) is creating, testing, and disseminating a larger number of shorter curriculum units (see <http://nanosense.org/>). A *Workshop to Identify and Clarify Nanoscale Learning Goals* (University of Michigan) has assembled the most significant and developmentally appropriate learning goals in nanoscience for grade 7–16 learners; a report is currently in draft form.

These projects are examples of the NSF research-based approach to NSEE curriculum development, which involves interviewing students to determine initial conceptual understandings; determining appropriate nanoconcepts and associated learning goals; developing valid and reliable assessments of student understanding; developing learning activities; pilot-testing, assessing, and revising the activities; conducting teacher professional development; broader field-testing, further revising, and disseminating the activities; and assessing student understanding. To date, projects are at the pilot-testing stage. Although we are some distance from incorporating nanoscience as a major thread in the K–12 curriculum, these projects are developing and testing models that ultimately could lead to widespread adoption.

Nanotechnology Undergraduate Education

Advances in nanotechnology research also provide new opportunities in undergraduate education. With their focus on imaging and manipulating atoms, NSE offers a multitude of new interdisciplinary teaching opportunities for engaging interest and for broadening vision by undergraduate students of science, engineering, and technology. In so doing, NSE makes possible new strategies for enhancing science and engineering literacy, preparing the workforce for emerging technologies, and attracting a diverse group of talented students to the workforce of tomorrow. The most recent competition (FY07) focused on nanoscale engineering education with relevance to devices and systems, and on the societal, ethical, economic and environmental issues relevant to nanotechnology. Nearly half the awards included funds to purchase equipment, such as scanning or atomic force microscopes, as part of the development of undergraduate courses, modules, or laboratory experiences.

Examples of Nanotechnology Undergraduate Education (NUE) awards in Engineering include: *Teaching Nanosystems Engineering to Early College Students with Active Learning Experiences* at Louisiana Tech University, which led to the Nation's first Nanosystem Engineering B.S. degree program; *Integrating Nanoscale Science and Engineering into the Undergraduate Engineering Curriculum* at the University of Wisconsin-Madison, which has made possible the introduction of a new course and revision of existing ones; and *Introducing Nanotechnology into the Curriculum at a Predominantly Undergraduate Institution* at Jackson State University, which created courses and research experiences at a historically black university. The NUE program has been funding these types of awards since FY04.

Nanoscale Informal Science Education

The *Nanoscale Informal Science Education Network* (NISE Net) was funded at the Museum of Science in Boston, in partnership with the Exploratorium in San Francisco and the Science Museum of Minnesota (along with initial collaborators: Oregon Museum of Science and Industry, North Carolina Museum of Life and Science, New York Hall of Science, Sciencenter in Ithaca, Fort Worth Museum of Science and History, Cornell University, University of Wisconsin-Madison, the Materials Research Society, and the Association of Science-Technology Centers). Now in its third year, NISE Net is establishing a national network linking science museums and nanoscale science and engineering research centers. It is developing exhibit units, educational programs, public forums, media, and other resources for implementation at more than 100 partner sites across the U.S. These activities will provide a wide variety of ways for the public to become engaged in and more knowledgeable about nanotechnology and provide a new model and national infrastructure for linking scientific research and informal education. Further information can be found at the NISE Net web site, <http://www.nisenet.org>.

NSF has invested in other Nanoscale Informal Science Education (NISE) awards aimed at increasing public understanding, such as *Earth and Sky Nanoscale Science and Engineering Radio Shows* and the traveling exhibition *Too Small to See*, which reached large family audiences at EPCOT Center in Florida and is now on tour to

science museums across the Nation. These awards were funded through the NSEE solicitation in FY04 and FY05.

Nanoscale Science and Engineering Centers Education and Outreach

Since 2001, NSF has funded the following Nanoscale Science and Engineering Centers (NSECs):

- * Center for Nanotechnology in Society (Arizona State University)
- * Center for Electron Transport in Molecular Nanostructures (Columbia University)
- * Center for Nanoscale Systems (Cornell University)
- * Science of Nanoscale Systems & their Device Applications (Harvard University)
- * Center for High Rate Nanomanufacturing (Northeastern University)
- * Center for Integrated Nanopatterning & Detection Technologies (Northwestern U.)
- * Center for Affordable Nanoengineering of Polymeric Biomedical Devices (Ohio State)
- * Center for Directed Assembly of Nanostructures (Rensselaer Polytechnic Institute)
- * Center for Biological and Environmental Nanotechnology (Rice University)
- * Center for Probing the Nanoscale (Stanford University)
- * Center of Integrated Nanomechanical Systems (University of California at Berkeley)
- * Center for Scalable & Integrated Nanomanufacturing (U. of California at Los Angeles)
- * Center for Nanotechnology in Society (University of California, Santa Barbara)
- * Center for Nanoscale Chemical-Electrical-Mechanical Manufacturing Systems (University of Illinois at Urbana-Champaign)
- * Center for Hierarchical Manufacturing (University of Massachusetts-Amherst)
- * Nano/Bio Interface Center (University of Pennsylvania)
- * Center for Templated Synthesis and Assembly at the Nanoscale (University of Wisconsin-Madison)

along with Nanotechnology User Facility Networks

- * National Nanotechnology Infrastructure Network (NNIN)
- * Network for Computational Nanotechnology (NCN)

and Materials Research Science and Engineering Centers, several of which focus on NSE.

These centers and facilities all conduct various forms of education and outreach that complement their primary research activities. The following list indicates the many types of programs that the centers and facilities develop and conduct:

- Research experiences and internships for teachers, undergraduates and high school students
- Courses and modules for undergraduates in two- and four-year colleges
- Professional development workshops and summer institutes for middle and high school teachers
- Hands-on activities for middle and high school classrooms and community organizations
- Tours, demonstrations, and Open Houses for visiting school groups
- Summer camps for middle and high school students
- Learning modules and kits for students
- Traveling exhibitions and public presentations for science museums
- Brochures on career opportunities for high school guidance counselors
- Web sites for students and the public
- Cable television broadcasts
- Planetarium show

Both formal and informal education components are required in the new solicitation to establish a Center for the Environmental Implications of Nanotechnology (CEIN), which is intended to conduct fundamental research and education on the implications of nanotechnology for the environment and for living systems. (This Center will be funded by NSF in partnership with the Environmental Protection Agency.)

Nanoscience and Engineering Education in Core Programs

In addition to those programs for which NSEE has been the primary emphasis, many other awards throughout NSF support education in NSE. For example, in addition to funding the previously-mentioned NISE awards, the *Informal Science Education* (ISE) program has funded projects, such as *Nanotechnology: The Convergence of Science and Society*. Through this award, Oregon Public Broadcasting is producing three one-hour nationally broadcast programs on the societal implications of nanotechnology using the Fred Friendly Seminar format. Other ISE awards include nanoscale science and engineering among other content areas, such as *Research Video News* by ScienCentral, which produces 90-second segments for national broadcast on commercial television news programs.

The *Advanced Technological Education* (ATE) program focuses on the education of technicians for the high-technology fields that drive our nation's economy. The program involves partnerships between academic institutions and employers to promote improvement in the education of science and engineering technicians at the undergraduate and secondary school levels. The ATE program supports curriculum development; professional development of college faculty and secondary school teachers; career pathways to two-year colleges from secondary schools and from two-year colleges to four-year institutions; and matriculation between two-year and four-year programs for K-12 prospective teachers. One example is the *Penn State Center for Nanotechnology Education and Utilization* (CNEU); its resources focus on incorporation of nanotechnology into K-12 education, post-secondary education, and industry applications. The work of CNEU has resulted in associate degree programs in nanofabrication at 20 institutions across the state, including every Pennsylvania community college.

The *Research Experiences for Teachers* (RET) program provides supplements to new or renewal NSF proposals by which Principal Investigators (PIs) can offer K-12 teachers and community-college faculty research experiences at the emerging frontiers of science, which include NSE. The goal of these supplements is to transfer new knowledge into the science classrooms. The *Research Experiences for Undergraduates* (REU) program provides similar types of supplements for research awards and also funds REU Sites for multiple students.

The *Centers of Research Excellence in Science and Technology* (CREST) program makes resources available to enhance the research capacities of minority-serving institutions by establishing centers that integrate education and research. CREST seeks to broaden participation of students historically under-represented in science and engineering, to promote the development of knowledge, and to increase faculty research productivity. Examples of the growing number of centers whose focus is NSE include: Tuskegee University's Center for Advanced Materials, the Center for Nanomaterials Characterization Science and Processing Technology at Howard University, and the Center for Nanobiotechnology Research at Alabama State University. A related program, *Louis Stokes Alliances for Minority Participation* (LSAMP), also supports NSE activities for both students and faculty.

Other efforts to broaden participation in NSE are funded through the *Experimental Program to Stimulate Competitive Research* (EPSCoR), which seeks to promote scientific progress nationwide. Examples are the New Mexico Nanotechnology Teacher Professional Development Workshops and the Center for BioModular Multi-Scale Systems (CBM²) Education and Outreach program at Louisiana State University.

The NSF *Graduate Teaching Fellows in K-12 Education* (GK-12) program provides funding to graduate students who work collaboratively with teachers and students in K-12 schools. These interactions are designed both to introduce students and teachers to frontier research, often based in NSE, and to enhance learning and instruction in schools. The *Integrative Graduate Education and Research Traineeship Program* (IGERT) funds interdisciplinary research-based, graduate education and training activities in emerging areas of science and engineering, such as NSE. Those awards include novel approaches to training, mentoring, career development, and other aspects of NSE graduate education to prepare students to enter the workforce and pursue research careers; they often also involve outreach to schools, science museums, and community organizations. Also, awards made in the *Faculty*

Early Career Development (CAREER) Program, which emphasizes the integration of research and education activities, frequently focus on NSE research.

In addition, many NNI-related research awards include education and outreach activities as a means to meet the Broader Impacts review criterion required of all NSF proposals.

Coordination and Evaluation

Within NSF, the diverse NSE and NSEE programs are coordinated, and priorities are determined, through the National Nanotechnology Initiative (NNI) Working Group chaired by Mihail Roco. This group meets regularly to discuss issues related to program planning and implementation, as well as budgets. NSF staff also participate on interagency committees, such as the Nanoscale Science, Engineering and Technology Subcommittee (NSET) of the National Science and Technology Council (NSTC) and its working groups. For example, I serve on the Nanotechnology Public Engagement and Communications (NPEC) Working Group. It provides a forum for sharing NSEE issues with representatives from other federal agencies. In this capacity, I assisted in organizing the Public Participation in Nanotechnology Workshop in May 2006, which brought together NSE representatives from government, industry, non-governmental organizations, media, and academia, including formal and informal educators. That workshop represented a first step towards engaging diverse stakeholders in educational and societal issues related to nanotechnology.

NSEE workshops were held in October 2005 and January 2007 to encourage creation of a community of practice among NSE educators from NSF-funded projects. The participants included representatives from formal education, informal education, and those conducting outreach at NSE research centers. In addition to fostering networking and collaboration, these workshops provided forums for exchanging ideas, sharing progress, and gaining complementary knowledge. In addition, NSEE project PIs participate in panels on education and outreach at the annual NSF NSE Grantees Conferences. Similarly, NSE research PIs and graduate students participate in the annual meetings of the NISE Network.

A third NSEE workshop is being planned for November 2008. It will include an international component to share perspectives and approaches to NSEE from other nations. Since many of the early NSEE projects will be close to completion by this time, the workshop will provide an opportunity to disseminate findings so that others can begin to build on the initial body of work. In addition, the workshop discussions will help inform NSF as it considers new opportunities for further investments in NSEE.

Planning at NSF will be further guided by a program evaluation planned by the Division of Research on Learning in Formal and Informal Settings (DRL) of awards made through the NSEE solicitations. Analyzing and synthesizing project reports, preparing case studies, and studying the impact of collaborations between NSE researchers and educators will add to our preliminary knowledge of NSE learning and teaching.

Nanotechnology in the Schools Act

The intent of the *Nanotechnology in the Schools Act* (H.R. 2436) to strengthen the capacity of high schools and universities to teach students about nanotechnology is commendable. However, the Administration has concerns that the program in the legislation is inappropriately structured to effectively meet this objective. For example, it is unclear that special equipment is a priority need to teach students nanotechnology effectively. Moreover, because nanotechnology is broadly defined as multi-disciplinary science and engineering at the molecular scale, "equipment" under the legislation could encapsulate a wide variety of routine tools and supplies that should remain the responsibility of recipient institutions or local education agencies, not the Federal Government.

To this end, the Administration recommends addressing the goals of the legislation through a variety of ongoing approaches by NSF. For example, several existing programs embed NSF funding of nanotechnology equipment purchases within comprehensive sets of integrated activities that are more likely to achieve intended educational outcomes. These grants enable PIs to develop innovative approaches to NSEE, and generally require formative and summative evaluation to ensure that the materials and approaches taken as a whole—not just tools and instruments—are effective with the target audience and that others can learn from and build on the knowledge gained.

In addition, cyber-enabled learning is beginning to suggest promising new directions for engaging students through growing resources for NSE images, simulations, and remote access to instrumentation. Students can even take part in virtual field trips. For example in one of the approaches tested in the *NanoLeap* project, high

school students “visited” the Stanford Nanofabrication Facility online, where they interacted with researchers in real time.

The Subcommittee should perhaps consider revisiting this issue after further knowledge has been gathered from current NSEE projects about the potential educational impact of the various approaches being developed for students in K–12 classrooms, two- and four-year colleges, and the public. Given the current limited state of knowledge about NSEE, the first priority is to determine which educational strategies are most effective for these different audiences based on research and evaluation. Such a direction also would be consistent with the increasing emphasis on research, development, and evaluation in NSF educational programs as preparatory steps towards implementation and scale-up.

Mr. Chairman, thank you again for allowing me the opportunity to testify on this important matter. I hope that these comments provide a helpful context for you as you continue to discuss best practices in addressing our national needs in science and engineering education.

I would be glad to answer any questions.

BIOGRAPHY FOR DAVID A. UCKO

David A. Ucko serves as Deputy Division Director for the Division of Research on Learning in Formal and Informal Settings at the National Science Foundation, where he was previously Section Head for Science Literacy and Program Director for Informal Science Education. Formerly, he served as Executive Director of the Koshland Science Museum at the National Academy of Sciences; founding President of Science City at Union Station and President of the Kansas City Museum; Chief Deputy Director of the California Museum of Science & Industry in Los Angeles; and Vice President for Programs at the Museum of Science & Industry in Chicago. Ucko was appointed by the President and confirmed by the Senate to the National Museum Services Board. He has chaired the Advocacy Committee and the Publications Committee of the Association of Science-Technology Centers. Prior to entering the museum field, he wrote two college chemistry textbooks while teaching at the City University of N.Y. and at Antioch College in Ohio. Ucko is a Fellow of the American Association for the Advancement of Science and a Woodrow Wilson Fellow. He received his Ph.D. in inorganic chemistry from M.I.T. and B.A. from Columbia.

Chairman BAIRD. Thank you, Doctor.

STATEMENT OF DR. NIVEDITA M. GANGULY, CHAIRPERSON, SCIENCE DEPARTMENT, OAK RIDGE HIGH SCHOOL, OAK RIDGE, TN

Dr. GANGULY. Thank you. Good afternoon, Chairman Baird, Ranking Member Ehlers, and Members of the Subcommittee. It is an honor today for me to appear before the Subcommittee to testify regarding the *Nanotechnology in Schools Act*.

I am the Chairperson of the Oak Ridge High School Science Department, and I have taught environmental science at the AP level, honors genetics, and freshman biology for 12 years. Before that I was a research scientist at the University of Tennessee-Knoxville and the University of California Irvine.

So I have taught at both levels. I have taught high school as well as college. I resigned from the university because I thought that if I was going to get students interested in science, it was not going to be at the university. They had already made up their minds what they wanted to do. Though I am not sure how much influence I have had, I think I can say that I have had an influence on some people.

And so I realize how important it is for us to start looking at cutting-edge technology and science at high school level.

We can teach and the premise that, you know, we are on the stage is slowly going out. That, there is no way you can do that. We would like to become the guide on the side, and one of the ways

to do that is to bring technology to our high school students. And we have at my high school. We teach AP biology, we teach DNA recombinant technology, but we were giving lectures and using paper and pencil as simulations. That is not what students will remember. They will listen to it, listen to me, listen to my colleagues, walk out the door 15 minutes later, and it is gone.

So we went ahead and bought the recombinant DNA technology equipment. I am going to use a few terms here. It is the PCR. It is called a Polymerase Chain Reaction machine. We bought those. We bought all the equipment that we need to do cutting-edge science for recombinant DNA technology. And we went and trained ourselves because we have to train ourselves before we can train our students.

So we went ahead and did that, and now it has become very commonplace. We can isolate our own DNA, cut it, and then run it out on gels, and the students can see what their DNA patterns look like. They will remember that. They will not remember if I stood up there and told them that this is what your DNA pattern looks like.

Nanotechnology in the Schools Act, when I heard about it, it was very, very exciting, not only for me, but for my students, because that is who I represent, my students. So for them to be able to handle that kind of technology in high school is something that is, if you told me this five years ago, it would have been mind boggling. I would say, no, you can't do it, but now we can. There is equipment which is user friendly enough that my students can use it.

There is an electron microscope which is a table top, which can be used by the students. I did electron microscopy in my previous life, and I know how complicated it is, but now if we have the equipment to do it, then our, my students can. And nanotechnology is not another subject. I am not trying to teach another subject. It is something that will apply across the board; in physics, in chemistry and biology, in environmental science—in every sphere of their learning.

I teach environmental science, and I talk about alternative energy, but then if I can have the nanotechnology to show how energy conservation can actually happen, they will remember that. They will not remember that I said that we have to turn off our lights when you walk out of the door. It is a much more powerful tool when they see it actually in their own hands.

The tools that are available now that we will be able to buy if we get the grant is something that my students will understand. They will be able to use, and our students can use it. My school has a very, you know, it is a unique situation. We have a lot of interaction with the scientists at the Oak Ridge National Lab, and we send our students there to use very sophisticated technology to do a lot of science. Last year they came in Fourth in the Siemens Science and Technology Competition. This year we were the national winners.

So if I had this equipment at my high school, it would not be three students that would have access to this kind of sophisticated technology. I would have a lot more students that would have the opportunity to use this technology and maybe not three students. This time maybe there would be 10 students, maybe in 10 years

there will be 30 students who will be excited because it is a sense of empowerment. They are doing the experiments themselves. They are looking at the results. They are looking at the data, and that is what they will remember. That is what will excite them, not me saying that this is what the tool is. The tool has to be in the hands of the students.

We are a high school which has some of the specialized equipment, but we are in the process, when we redesigned our high school and it is still in the construction phase, we are still hopping over little construction, little sites everywhere, there, we are equipped to handle distance learning. And so what we would like to do is use that to reach out to the community around us, to other schools who may not have that kind of access to the equipment that we have.

We already run the AP Summer Institutes to expose teachers from across the country to the different technology and the different ways of teaching an AP class. When we have our distance learning system set up, we will bring students to our high school in the summers to run these kind of programs to expose them to these things.

So it is something that we can do, and I firmly believe that our students are bright enough and are capable enough to be able to handle this. And I am not talking about——

Chairman BAIRD. Dr. Ganguly, I am going to ask you to summarize here, because we are——

Ms. GANGULY. Yes. That would it. I am not just talking about my upper-level students. I would like to expose all students at all levels to this kind of technology if it is available to us.

I would be happy to answer questions.

[The prepared statement of Dr. Ganguly follows:]

PREPARED STATEMENT OF NIVEDITA M. GANGULY

Chairman Baird, Ranking Member Ehlers, and Members of the Subcommittee, it is an honor to appear before you today to testify regarding the *Nanotechnology in the Schools Act*, H.R. 2436. I am the chairperson of the Oak Ridge High School Science Department, and have taught Biology Honors, AP Environmental Science and Genetics Honors at Oak Ridge for 12 years. As a science educator, I believe that we must offer our students the learning opportunities that will prepare them to lead the world in scientific research. The Nanotechnology in the Schools Act helps accomplish this goal by allowing high school science departments like mine to teach hands-on nanotechnology, which is key to a competitive science education in the 21st century.

Nanotechnology is not a branch of science, like physics or biology. Rather, it is a new field that applies to many different branches of science. Nanotechnology is at the leading edge of chemistry, molecular biology, engineering, and other disciplines. Because it is so fundamental, our students need to understand it. The best way for them to understand it is to experience it firsthand, and that means having access to nanotechnology tools in the classroom. For the first time, these tools are becoming affordable enough—and user-friendly enough—that high schools like mine can begin to consider purchasing them. The *Nanotechnology in the Schools Act* will make that decision easier, and will help us put these tools in the hands of our students much sooner.

I would like to respond to a series of questions from the Subcommittee:

Please describe your experiences using high-tech scientific equipment in the high school classroom. What benefits do you feel students would receive from having the opportunity to work with nanotechnology equipment?

Students have an inherent interest in most things that are related to technology. At Oak Ridge High School we use equipment which we think is relatively high-tech

in relation to biotechnology. We have a Polymerase Chain Reaction (PCR) machine, electrophoresis equipment, centrifuges, UV lamps, and so on. This equipment allows us to actually do the experiments instead of doing them as simulations using pencil and paper.

When students use the equipment they truly understand the complexity and the principles behind the science of biotechnology. They realize how much precision and concentration is required at the bench because it is very easy to make mistakes if you are not paying attention to detail. There is no way they will understand this from a textbook, lectures or simulations.

The use of Geographic Information System (GIS) equipment in AP Environmental Science allows students to get measurements in geology, soil science, water situations, population issues across the globe.

Nanotechnology is becoming a science of the future. Currently, we just mention it in class, and students cannot visualize what a powerful tool it can become. With some basic nanotechnology tools, we will be able to focus more on nanotechnology, and the students will be able to do it themselves.

With the myriad topics high school science teachers must currently cover, how do educators strategically choose new experiences for students in the sciences? How do you integrate the newest concepts into the curricula to give students an appreciation for the new material and an excitement about science, as well as a deeper understanding of the fundamentals?

Of course, the fundamentals have to be taught, and they are. But exposure to advanced technology, innovative software and sophisticated equipment leads to an increased understanding of the material because one can get data which has been generated by them. Nanotechnology is a field that applies broadly to a full range of scientific disciplines, and the concept at its core—that matter can behave in importantly different ways at the nanoscale—is critical to modern science education.

Generating excitement about science at the high school level is crucial if we want American college and graduate students in science programs. Hands-on science is exciting—especially when it involves exploration. Nanotechnology opens up fascinating new worlds within even the most ordinary objects. With an electron microscope, for example, a student can discover the structure of a cell or the pattern of fissures in a piece of metal. For the first time, students can see the microorganisms that share their world—and as anyone who has looked that closely can tell you, it is a compelling sight.

What kinds of professional development opportunities would teachers need to help them integrate nanotechnology into their curriculum and properly use and maintain high-tech equipment?

Professional development is very, very important. Teachers are willing to learn and try new things—we are life-long learners—but without the proper training we will not feel comfortable trying to incorporate the new technology into our class room teaching. Once we are comfortable, we can use the tools in a variety of formats. The *Nanotechnology in the Schools Act* provides for professional development and teacher education within the grants, and I understand that efforts are already underway to develop curricula based on nanotechnology tools.

Are there problems obtaining funds needed for the maintenance of high-tech equipment? How does Oak Ridge High School address these?

There may be issues with funding in some school systems, but at Oak Ridge we have the Oak Ridge Educational Foundation which helps with these issues. As a department, we also write grants for extramural funding. It may not be huge sums of money but every little bit helps and it allows us to try innovative teaching strategies, which is sometimes not possible on a school budget. We are fortunate to have these resources available to us, and we recognize that many other schools with talented students do not have such resources. The Nanotechnology in the Schools grants will help those schools as well. That said, adding a provision for maintenance funds may improve the program.

As part of the redesign of our new High School, we are going to have the capability of holding distance learning classes. Even though it is not in place yet, because we are still in the middle of construction, it will happen in the next couple of years. Some of the rural schools around us are not able to offer some of the advanced classes because of the lack of trained faculty and inadequate facilities. We would like to be able to fulfill that gap through our long-distance learning program and holding summer workshops where we will expose those students to our facilities.

Students, no matter at what level, always respond better to situations where they are actively involved in their own education process. As department chair, I have tried to make sure that all students at all levels have the opportunity to use any equipment that is available in the department. It is true that we may not be able to convert every one to become a scientist, but if we are able to change the mind of a handful, who think science is fun, I will consider that a success.

Again, thank you for the opportunity to testify today about high school science education and the *Nanotechnology in the Schools Act*. I am happy to answer any further questions you may have.

BIOGRAPHY FOR NIVEDITA M. GANGULY

CITIZENSHIP

United States of America

EDUCATION

41992—M.S. in Science Secondary Teaching, University of Tennessee
 1975—Ph.D. in Genetics, University of Calcutta, India
 1967—M.S. in Zoology & Comparative Anatomy, University of Calcutta, India
 1965—B.S. with major in Zoology, minor in Botany and Human Physiology, University of Calcutta, India

EMPLOYMENT

2002—present—Department Chairperson
 1995—present—Science Teacher, Oak Ridge High School, Oak Ridge, TN
 1992–1995—Science Teacher (Tenured), Bearden Middle School, Knoxville, TN
 1991–1992—Science Intern, Robertsville Junior High School, Oak Ridge, TN
 1987–1991—Research Associate, Department of Zoology, University of Tennessee, Knoxville
 1981–1986—Research Associate, Department of Molecular Biology & Biochemistry, University of California, Irvine
 1977–1980—Research Associate, School of Life Sciences, University of Nebraska, Lincoln
 1973–1976—Visiting Research Scientist, NIEHS, Research Triangle Park, North Carolina

TEACHING EXPERIENCE

1995—present—AP—Environmental Science, Genetic(Hons)s, Honors Biology , Oak Ridge High School
 1992–1994—7th Grade Honors Science, Bearden Middle School, Knoxville, TN
 1991–1992—Ninth Grade Biology, Robertsville Junior High School, Oak Ridge, TN
 1988–1990—Undergraduate Cell Biology, University of Tennessee, Knoxville
 1974–1975—Undergraduate Genetics, University of North Carolina, Chapel Hill

HONORS AND AWARDS

2006—Invited to Be the College Board Advisor for AP Environmental Science
 2006—Member of Committee to Draft Leader's Notes for One-Day AP Workshops
 2005—Endorsed National Leader for the College Board
 2004—Author, *AP Vertical Teams Guide*
 2000—Siemens Award for the teaching of Science. Awarded to 20 teachers nationwide
 2000—Award from the Presidential Council of Environmental Education. Awarded to 35 teachers nationwide.
 1997—Invited to participate in the River-to-River Exchange Program to Russia

- 1995—Invited to participate in the Governor's Academy of Science and Math at University of Tennessee
- 1995—Invited to participate in Train the Trainers workshop, AP Environmental Science at Dartmouth College
- 1994—21st Century Classroom Award from the Knox County School System
- 1994—Minority Teacher Research Fellowship to work on Invertebrate Zoology at the University of Tennessee, Knoxville
- 1993—Minority Teacher Research Fellowship to work on Ecology and setting up an Ecological Center at Powell Elementary School, Powell, TN
- 1991—DOE/Lyndhurst Fellowship for Secondary Science Teaching Certification
- 1973–76—Visiting Fellowship from the National Institutes of Health, USA

RELATED SKILLS

- Introduction to Computers and Operating System, Pellissippi State Technical College
- Radioisotope Techniques, North Carolina State University
- Mammalian Genetics, Jackson Laboratory, Bar Harbor, Maine
- Cytological & Electron Microscopic Techniques, University of California, Irvine
- Recombinant and Molecular Biology Techniques, University of Tennessee, Knoxville

OTHER ACADEMIC ACTIVITIES

- 2003—Invited to be an author in the 2003 Teacher's Guide for AP Environmental Science
- 2003—Member of 8-person team of teachers that wrote the *Manual for AP Vertical Teaming in Science*
- 1998–present—Reader (grader), Table Leader in AP Environmental Science
- 1998–present—College Board Consultant for AP Environmental Science. Presenter for both 1-day workshops and weeklong Summer Institutes.
- 2003–present—College Board Consultant for Pre-AP strategies in Science: Learner Centered Classroom
- 2004–present—College Board Consultant for AP Vertical Teams in Science. Presenter for both 1-day and week long workshops.
- 1998–present—Sponsored and Coached Science Olympiad Team. State Winners 8 times. Have represented Tennessee at National Competition 8 times.
- 1998–present—Sponsored and coached Science Bowl team. State winners 5 times.
- 2000–present—Sponsored and coached Envirothon team. State winners twice.
- 1997—Invited to help teach part of a course at the Academy of Science and Math, University of Tennessee, Knoxville
- 1991—Coached Science Olympiad Team, Robertsville Junior High School, Oak Ridge, TN
- 1992–1995—Coached Science Olympiad Team, Bearden Middle School, Knoxville, TN
- 1993–1995—Organized Science Fair at Bearden Middle School, Knoxville, TN

MEMBERSHIP AND PROFESSIONAL SOCIETIES

- National Educator Association
- National Science Teacher Association
- TSTA
- TEA
- OREA
- GSA

COMMUNITY ACTIVITIES

- Member of Committee of Stakeholders, along with community leaders involved in tile designing of a new Oak Ridge High School
- Member of ORSSAB (Oak Ridge Site Specific Advisory Board)—involved with environmental cleanup issues on the Oak Ridge Reservation
- Member of SQUAB (Environmental Quality Board) in Oak Ridge
- Teach Dance to Children of Asian Indian Association of Knoxville

OTHER INTERESTS

Aerobics, Dancing, Stamp Collecting, Reading.

PAPER PRESENTATIONS

Total of 15 presentations

1. 13th International Congress of Genetics, Berkeley, California, 1973. Presented paper entitled: "Induction of dominant lethal mutations in male mice by four individual chemicals."
2. 3rd International Conference on Differentiation & Neoplasia, Minneapolis, 1978. Presented paper entitled: "Functional differentiation and neoplastic transformation of whole mammary gland."
3. 15th International Congress of Genetics, New Delhi, India, 1983. Presented paper entitled: "Isolation and characterization of glucose 6-phosphate dehydrogenase gene of *Drosophila melanogaster*."

PUBLICATIONS

Articles in books & monographs (representative papers)

1. Banerjee, M.R., N. Ganguly, N.M. Mehta, A.P. Iyer, and R. Ganguly (1980) Functional differentiation and neoplastic transformation in an isolated whole mammary organ in vitro. In: *Cell Biology of Breast Cancer*, C.M. McGrath, M.J. Brennan and M.A. Rich, eds. Academic Press, N.Y. pp. 485–516.
2. Banerjee, M.R., R. Ganguly, N.M. Mehta and N. Ganguly (1982) Hormonal regulation of casein gene expression in normal and neoplastic cells in murine mammary gland. In: *Hormone regulation of experimental breast tumors*. Benjamin Leung, ed., Eden Press, vol. 2, pp. 229–283.
3. Banerjee, M.R., N.M. Mehta, R. Ganguly, P. Majumdar, N. Ganguly and J. Joshi (1982) Selected gene expression in an isolated whole mammary organ in vitro. In: *9th Cold Spring Harb. Conf. Cell proliferation*. Sibrasku, G. Sato and A. Pardee., eds., pp. 789–805.

Articles in refereed Journals (representative papers)

4. Ganguly, R., N.M. Mehta, N. Ganguly and M.R. Banerjee (1979) Glucocorticoid modulation of casein gene transcription in mouse mammary gland. *Proc. Natl. Acad. Sci. (USA)* 76, 6466–6470.
5. Mellta, N.M., N. Ganguly, R. Ganguly and M.R. Banerjee (1980) Hormonal modulation of the casein gene expression in mammosgenesis—lactogenesis two-step culture model. *J. Biol. Chem.* 255, 4430–4434.
6. Ganguly, R., N. Ganguly, N.M. Mehta and M.R. Banerjee (1980) Absolute requirement of glucocorticoid for expression of the casein gene in presence of prolactin. *Proc. Natl. Acad. Sci. USA* 77, 6003–6006.
7. Ganguly, N., R. Ganguly, N.M. Mehta and M.R. Banerjee (1981) Simultaneous occurrence of pregnancy-like lobuloalveolar morphogenesis and casein gene expression in a culture of the whole mammary gland. *In vitro* 17, 55–59.
8. Ganguly, R., P. Majumdar, N. Ganguly and M.R. Banerjee (1982) The mechanism of progesterone-glucocorticoid interaction in regulation of casein gene expression. *J. Biol. Chem.* 257, 2182–2187.
9. Ganguly, N., R. Ganguly, N.M. Mehta and M.R. Banerjee (1982) Growth and functional differentiation of hyperplastic mammary cells of Balb/c mouse transformed in vitro. *J. Natl. Cancer Inst.* 69, 453–463.

10. Levy, L.S., R. Ganguly, N. Ganguly and J.E. Manning (1982) The selection, expression and organization of a set of head-specific genes in *Drosophila*. *Dev. Biol.* 94, 451–464.
11. Ganguly, R., N. Ganguly and J.E. Manning (1985) Isolation and characterization of glucose 6-phosphate dehydrogenase gene of *Drosophila melanogaster*. *Gene* 35, 91–101.

Chairman BAIRD. Thank you very much and congratulations on the achievements of your students. It is very impressive.

We have been joined by Mr. Neugebauer from Texas as well.

Dr. Fraser.

STATEMENT OF DR. HAMISH L. FRASER, OHIO REGENTS EMINENT SCHOLAR AND PROFESSOR, DEPARTMENT OF MATERIALS SCIENCE AND ENGINEERING, OHIO STATE UNIVERSITY

Dr. FRASER. Chairman Baird, Ranking Member Ehlers, and distinguished Members of the Subcommittee, thank you for your invitation allowing me to be here and join this hearing this afternoon.

I have been in academia for about 35 years, about half of that as an Illini and more recently as a Buckeye at Ohio State. I have graduated about 40 Ph.D. students, 40 MS students, and several hundred of engineering undergrads have been exposed to my teaching and help, I hope.

My area of expertise is in advanced materials characterization, which is an enabling part of nanotechnology, and which is being able to see the material that is made that is on such a fine scale. My area is such that I interact with the industrial areas of aerospace and automotive materials.

So the equipment we use is extremely expensive, very sophisticated, and quite costly to maintain. So naturally it is the subject of a graduate focus, where we can get reasonable funding from the Federal Government to help us in that research activity.

But another part of my job, of course, is to be concerned about development of the workforce in the area of material science and engineering and also in nanotechnology. So education in any of these areas is important. This afternoon we are talking about nanotechnology. I have been working this issue quite vigorously, using local funding to do that, and what I have found most effective is to capture the imagination of the kids. Materials characterization is a very, very effective way of doing this, and I want to show—next view graph, please.

What you see on the first image is just a shiny, gray piece of metal. It happens to be an advanced titanium alloy used in aerospace applications. It looks rather dull, of course, because it just looks like a piece of shiny metal, but if you look at this at higher magnification, next view graph, please, you now see details of the microstructure. You will see that that scale marker is five micrometers, and a human hair is about 40 micrometers in diameter, to get an idea that we are extremely high magnification where all the fun is happening in the material and all the properties are being determined. This is what will turn the kids on.

Another example, click, please, would be the eye of a fly. It looks like one of those things that buzzes around you, and you can even magnify the lens of the eye, click, please, and you will see that there are other features there.

These are things that can be seen by these tabletop SEMs. Now, this is the type of thing that captures the imagination of these kids and will enable us to, I believe, to attract them into science, technology and engineering.

So specifically I am very excited about this bill because I believe a difference is that this bill will put equipment in the classroom for professors and high school teachers to use with the students, and the important thing about characterization equipment is that they will be able to see the stuff, which they will not be able to do with their eyes.

So, specifically, I think we need to capture the imagination of the students, and this will draw a significant number of students into the subject. This bill will provide equipment and the development of class modules, to allow a wide number of faculty to be able to teach this subject who are not yet able to do so because of their backgrounds. And I think it will greatly assist in developing the requisite workforce.

Conversely, it will prepare our students for quite high-paying jobs where there is, in fact, a great demand and a growing demand, and that will permit us to remain globally competitive.

Actually I cut a little bit out of what I wanted to say, because I wanted to pick up on Ranking Member Ehlers' comment about the need to impact all schools. I think you made an extremely important point there.

I would like to offer an opinion of why I think this bill can actually address your point. It is a very good point that we need to have equipment at the schools, but we need particular kind of equipment. The normal equipment you find at industry and universities is too complicated for schools to use. I bought a new scanning electro-microscope some years ago at about \$180,000 for undergraduate programs. It has not been used yet by my faculty because it is just too complicated to bring into the classroom. You need the simplified equipment, which modern development has allowed.

Also we need to develop educational modules for teachers to be able to use the instruments, and this bill would allow that. In addition to the equipment, I think we need to have PC-based simulators of this equipment that will fit on every computer in every lab in every school. So the use of the equipment will be much greater than just where the actual instrument resides. The simulators will do a very good job, and we have used those, and they are very effective.

I hope I was able to address your point somewhat.

[The prepared statement of Dr. Fraser follows:]

PREPARED STATEMENT OF HAMISH L. FRASER

Preamble

I have been invited to testify before the Subcommittee on the current state of education in nanotechnology within *undergraduate* serving institutions and to offer my opinion concerning ways in which this education can be enhanced at such institutions. This is a particularly important subject at the present time as nanotechnology is without doubt a major global focus where a competitive advantage will be accrued by those nations having a workforce which is broadly educated in nanotechnology. Through research, the U.S. currently has a competitive advantage, but maintaining this advantage will depend on the development of a well-educated workforce that is able to exploit the various research thrusts by realizing commercial products from ideas. In the following, I assess briefly the current status of undergraduate edu-

cation in nanotechnology and discuss ways of enhancing this by answering the questions posed to me by the Chairman of the Subcommittee, Congressman Baird.

Current Status: Nanotechnology in Undergraduate Education

As a result of the vigorous focus on nanotechnology, underscored by the National Nanotechnology Initiative (NNI), there has been a development of courses and degree programs that involve nanotechnology. The vast majority of these activities are aimed at graduate education, where programs involving M.S. and Ph.D. degrees in the subject have been established, and courses are included in the offerings in various science and engineering programs. The degree to which nanotechnology has been included in undergraduate education is much less than that at the graduate level, and has involved efforts such as NSF's *Research Experience for Undergraduates* programs at a number of institutions. For example, according to the NNI, there are five graduate degree programs and two associate degree programs (provided in conjunction with research universities) focused explicitly on nanotechnology, but no B.S. programs are listed. The reason for this lies in the fact that progress in nanotechnology is the result of execution of vigorous research programs. These are almost exclusively undertaken in our nation's major research universities, and hence the immediate fallout regarding education involves graduate programs in these institutions.

Barriers to Undergraduate Nanotechnology Education

In addition to the concentration of activity in nanotechnology being in the research programs of our universities, there are two other major problems that need to be addressed in order to realize curricula that will serve as an attraction to students such that a significant workforce may be developed. Firstly, in general the equipment required for such curricula, for processing, characterization and property assessment of nanomaterials and nanodevices, is currently expensive to acquire and is complicated to operate. For example, it would be necessary for much of this equipment to be operated by an expert, which would increase an instructional budget significantly. Equally important is the cost of maintaining such equipment, again imposing a financial burden on the establishment of an undergraduate program.

The second problem involves, on the part of faculty at a large number of our nation's academic institutions, the lack of experience and knowledge required to develop an undergraduate program involving nanotechnology, especially regarding the operation and maintenance of equipment for either demonstrations in lectures and/or laboratory classes, which are essential in any undergraduate program. In general, the equipment required to develop attractive undergraduate laboratory classes on nanotechnology, including instruments that produce nanomaterials, characterize them and measure their properties, are found in research laboratories and are often rather sophisticated and complex. This lack of familiarity inhibits faculty from fully developing effective and attractive courses in the subject.

It is my understanding that the proposed bill, H.R. 2436, aims to obviate these barriers to permit effective and attractive courses to be developed.

Answers to specific questions:

In the following, I have taken the liberty of reversing the order of questions 2 and 3, because the answer to the second question draws on the answer to the third. I have indicated the original order of the questions.

Question 1: Please describe current nanotechnology education efforts at the undergraduate level. As new fields emerge in science, how do university science departments merge them into the current undergraduate curriculum?

I have made reference above to the current state of inclusion of nanotechnology in undergraduate studies, where the main efforts to include nanotechnology in curricula are taking place at the graduate level. Regarding the merging of new fields into undergraduate curricula, generally faculty at major research universities, especially those with research components involving a new technology, will add in an *ad-hoc* manner, content to their existing classes and develop new classes that focus on the given new technology. Such developments will take place at a slower pace at other tier 1 and tier 2 and 3 colleges. As an example, consider the inclusion in undergraduate curricula of a different, but important, novel technological area, namely computational materials science (i.e., the modeling and simulation of the behavior and performance of materials). Having declared this a thrust area of our department at Ohio State, and hiring three new faculty members in this area, a highly successful undergraduate course has been developed. This was not attempted prior to the employment of these faculty members with the appropriate research expertise

mainly because the existing faculty did not have the requisite knowledge and familiarity with the subject.

Of course, as a given technology matures, and its body of literature broadens, it is possible for faculty with little initial familiarity with the subject matter to develop undergraduate course material by drawing on this body of literature. However, in the context of the currently proposed House Bill, aimed in part, “to maximize the benefits of nanotechnology to individuals in the United States,” it is important to develop the course material at an early stage of the development of this technology and hence indeed maximize potential benefits.

Question 2 (originally question 3): What types of nanotechnology equipment could be used for educational benefit at the undergraduate level?

Generally, there are three types of equipment required for study of nanomaterials and/or nanodevices, which are for processing materials and devices, for their characterization, and for measuring their properties. In principle, undergraduate courses on nanotechnology would benefit from the provision of all three types of instrumentation. However, in the following, I will argue that because of constraints of budget, a focus should be maintained on materials characterization, as indicated in the proposed House Bill.

Regarding processing equipment required to produce nanomaterials and nanodevices, this tends to be of a specialist nature and not necessarily commercially available. Where it is available for purchase, it tends to be rather costly, requiring an expert for operation and significant maintenance expense. In addition, the study of a range of nanomaterials and nanodevices would require the acquisition of a number of pieces of processing equipment since a given instrument is usually focused on the processing of a given material type (e.g., a magnetron sputtering device used for deposition of nanoscaled multi-layered materials would not be used to grow carbon nanotubes). These issues also apply to equipment required to measure properties and performance of nanomaterials and nanodevices. For example, there is a wide range of properties that in a comprehensive study would be the subject of measurement, i.e., optical, electrical, magnetic, and mechanical, and each of these would require specific instrumentation to make the requisite measurements.

Equipment for characterization offers a number of significant advantages regarding the provision of attractive undergraduate courses in nanotechnology. Regarding the issues raised above, concerning the need for a number of different instruments to process a wide variety of materials, or to measure a broad range of properties, a single instrument for characterization can make observations of a wide variety of materials types. Perhaps most importantly, is the ability to see the products of nanotechnology. This ability to *observe* micro- and nano-structures is a key to attracting students to physical sciences and engineering, and, of course, nanotechnology. To serve as examples, please refer to the two figures. Figure 1(a) shows an image of an advanced titanium alloy that is used in aerospace applications. It appears to be a simple shiny piece of metal, grey in color. However, when imaged in the scanning electron microscope (Figure 1 (b)), its rich microstructure is revealed, and it is these nanoscaled features that govern the properties and performance of these alloys. For reference, a human hair is approximately $40\mu\text{m}$ in diameter. The second example involves the imaging of the eye of a fly in the scanning electron microscope, Figure 2 (a). Increased magnification reveals finer scaled structure, see Figure 2 (b). It is the observation of these regarding the development of attractive undergraduate courses.

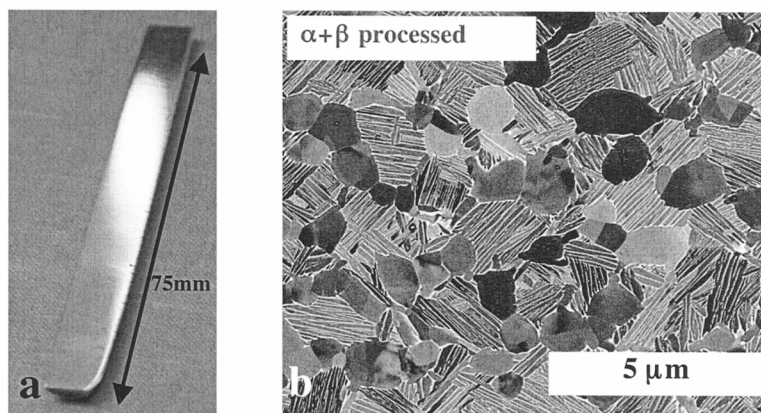


Fig. 1. (a) An image of an advanced titanium alloy captured with a digital camera. (b) The same material observed in a scanning electron microscope revealing microstructural features.

To reveal these nano-scaled features requires the use of equipment with the appropriate resolving power. A number of instrument types may be used, but a most appropriate machine for use in undergraduate education is the scanning electron microscope, largely because of its simplicity of use. This is particularly the case for recently developed table-top scanning electron microscopes, where the operating system and procedures have been very much simplified, and the costs of ownership and maintenance have been significantly reduced. It is because of the impact of effective materials characterization of nanomaterials and nanodevices on attracting students, and the more recent developments regarding ease of use and reduced costs that, in my opinion, materials characterization can be the basis for the development of very effective undergraduate courses in nanotechnology.

Question 3 (originally question 2): How would a grant program, like the one proposed by H.R. 2436, be used by undergraduate serving programs? At the college level, does the opportunity to work with new technology draw in students who might otherwise have been uninterested in science? Do hands-on experiences offer a unique learning opportunity that is difficult to replicate in a lecture?

The proposed grant program would be used in two ways to impact undergraduate programs. Firstly, a part of the funding would be used to develop undergraduate educational modules that would include versions for both teachers and students. These modules would be lecture-based courses where experiments involving materials characterization (following my conclusion above) would be included, and also laboratory courses that would be instrument intensive. These developed materials would then be available for use by other tier 1, 2 and 3 institutions. Secondly, the funds provided by a grant could be used to acquire a table-top scanning electron microscope, augmented by the provision of PC-based scanning electron microscope simulators, for use in the combination lecture/laboratory modules and the laboratory classes themselves. It is worth noting that at present, university faculty have almost no access to funding to assist in the development of undergraduate courses that would be coupled with in-class experiments, as proposed here, and to acquire the necessary hardware. The proposed House Bill H.R. 2436 would fill an important gap.

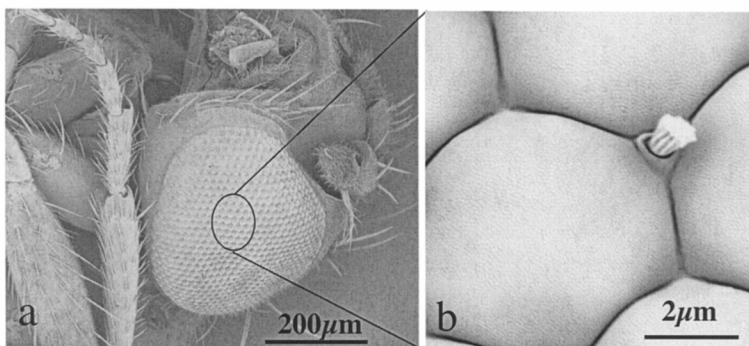


Fig. 2. (a) A scanning electron microscope image of an eye of a fly. (b) Magnified image revealing refined structural details of the eye.

Without doubt, the opportunity to work with new technology acts as a tremendous draw for undecided students. But students tend to be rather clever and have usually done their homework regarding the impact that studying new technologies will have on their careers (particularly regarding employment!), and will make their choices accordingly. Nanotechnology is not only new, but its economic implications are not missed by the students. Promoting attractive undergraduate courses in nanotechnology will lead to increased numbers of students studying science and technology and will provide for a suitably trained workforce.

Our experiences with the provision of laboratory classes in undergraduate curricula are in concert with the notion that hands-on experiences are essential. But, it is important to point out that lecture courses are efficient methods of covering much basic groundwork in a given subject for a significant number of students. However, such courses can be very significantly enhanced by combining lectures with hands-on experiences as I have noted above.

BIOGRAPHY FOR HAMISH L. FRASER

Dr. Fraser is currently Ohio Regents Eminent Scholar & Professor of Materials Science & Engineering in the Department of Materials Science & Engineering at the Ohio State University, and Professor of Materials Science and Technology (Hon.) at the University of Birmingham (UK). He received his BSc (1970) and Ph.D. (1972) from the University of Birmingham (UK). He was on the faculty of the University of Illinois from 1972–1989. He has graduated 41 students with the degree of Ph.D. and 33 students with the degree of MS. He has been a member of both the National Materials Advisory Board (2000–2006), and the U.S. Air Force Scientific Advisory Board (2002–2006). He is a Fellow of ASM (1993), the Institute of Materials (2001), and TMS (2005). In 2006, he was awarded a Senior Research Prize by the Alexander von Humboldt Foundation in Germany. He has served as a consultant for NATO, the Governments of Great Britain and Western Australia, and currently consults for the Air Force Research Laboratory in Dayton, OH. His research interests include materials characterization, inter-metallic compounds, nano-scaled metallic multilayers, light alloys (mainly Ti alloys), and development of research tools for the prediction of microstructure/property relationships in materials. He has published more than 330 scholarly publications and presented more than 200 invited talks.

Chairman BAIRD. Thank you very much, Dr. Fraser.
Dr. Vandiver.

STATEMENT OF DR. RAY VANDIVER, VICE PRESIDENT OF NEW PROJECT DEVELOPMENT, OREGON MUSEUM OF SCIENCE AND INDUSTRY

Dr. VANDIVER. Mr. Chairman, Ranking Member Ehlers, Members of the Subcommittee, thank you for inviting me to testify today

about the ways in which nanotechnology education can help inspire people to pursue careers in science, the importance of nanotechnology as an element of 21st century science education, and the key role of informal science education in this process.

I serve on the staff of the Oregon Museum of Science and Industry, known as OMSI, a non-profit, independent, scientific, educational, and cultural resource center dedicated to improving the public's understanding of science and technology.

Informal science centers such as OMSI play an important role in math and science education at all grade levels through permanent and rotating exhibits, teacher training and professional development programs, and distance learning initiatives that are able to reach small and isolated communities. Science centers and museums are able to compliment and enhance efforts at schools in a large geographic region, providing expertise and programs on a large variety of science subjects.

Science and technology centers are motivated to present emerging and cutting-edge concepts in science and technology. It is inherent in our missions to strive to present the latest achievements and breakthroughs. Nanotechnology is an important component of OMSI's educational mission in inspiring, informing, and involving our visitors in cutting-edge scientific research.

It is only recently that tools and equipment in the forms of exhibits, simulations, and models on the subject of nanotechnology have been developed and tested with museum educators and museum visitors. Nano is a difficult and abstract topic to tackle in the informal setting. Additional resources are needed to help our field advance new methods for creating context and relevance for our audiences.

The Nanoscale Informal Science Education Network, NISE-Net, an NSF-funded initiative, is working to develop some resources from museums on the topic of nanotechnology. NISE-Net, currently beginning its third year, has as its goal to create a functioning network of 100 science and technology centers across the United States, working together to represent the nature and potential impacts of nanoscale science and technology.

This is a powerful vision, and it is the largest collective effort across the field of science and technology centers to advance knowledge and understanding of a specific topic, nanotechnology. As a member of NISE-Net, OMSI is active in the development of exhibits and programs designed to inform the general public of the topic of nanoscale science and engineering.

Because the general public knows very little about nanoscale science and its applications, OMSI's approach, consistent with the other working partners of NISE-Net, is to present nanoscale science and technology in a way that inspires wonder and motivates the user to seek more depth and understanding of the topic.

The front-end work within the NISE-Net has shown that less than half of the adult population of the United States has ever heard of nanotechnology, and less than 20 percent can provide any level of basic definition. However, the studies also show that the general public is interested in the topic and possesses a positive sense about nanotechnology.

You know, in all my years in physics research and science education, I can only think of one time that my father, who is a carpenter in St. Louis, Missouri, has ever contacted me, requesting information about emerging technology, and that was nanotechnology. So that was pretty cool.

While most people think of the science museum as a place to go to have a fun family science learning experience, most science museums also provide community learning opportunities outside their walls. This can be in the form of teacher training, distance learning, and classroom programs. OMSI, for instance, provides distance learning opportunities throughout Oregon and southwest Washington. As an example, OMSI works with educators in rural Fossil, Oregon, population of less than 500, to provide resources in science learning experiences that they would not otherwise have access to.

Science centers such as OMSI could take advantage of this new nanotechnology education grant program, which could help to purchase advanced equipment and educational materials, enabling outreach and teacher development for many schools and communities.

In conclusion, I would once again like to thank the Subcommittee for your attention to this important issue. Our future as a nation of discoverers, inventors, and innovators depends on education and inspiration. I believe that the *Nanotechnology in the Schools Act* will help insure that our scientific future stays bright.

I look forward to the opportunity to take advantage of this program.

[The prepared statement of Dr. Vandiver follows:]

PREPARED STATEMENT OF RAY VANDIVER

Mr. Chairman, Ranking Member Ehlers, and Members of the Subcommittee, thank you for inviting me to testify today about the ways in which nanotechnology education can help inspire people to pursue careers in science, the importance of nanotechnology as an element of a twenty-first century science education, and the key role of informal education in this process.

I serve on the staff of the Oregon Museum of Science and Industry (OMSI)—a non-profit, independent, scientific, educational, and cultural resource center dedicated to improving the public's understanding of science and technology. Founded in 1944, OMSI is considered one of the top ten science centers in the United States and has earned an international reputation in science education. Its facilities include a 219,000-square-foot museum featuring five exhibit halls, eight hands-on public labs, a planetarium, an OMNIMAX theater, and the USS *Blueback* submarine. OMSI also offers a wide range of educational and outreach programming, including residential camps, summer classes, museum camp-ins, after-school science clubs, and traveling programs that deliver hands-on experiences to communities throughout Oregon and six other western states. In addition, OMSI provides professional development opportunities for K-12 teachers, including workshops, a science teaching resource center, and distance-learning programs targeted at educators in rural communities.

The Teacher Education Department at OMSI is uniquely positioned to provide teacher professional development programs in Science, Technology, Engineering, and Math (STEM) education throughout the northwest. Distance education technology, supporting delivery of professional development, allows OMSI to contribute our five decades of science education experience to a national and even international audience through live video-conferences and on-line, on-demand server-based programs. Currently, this type of flexibility, combined with a world-class facility and staff, make OMSI a significant resource for teachers worldwide.

In 2003 OMSI began working with rural communities in Oregon to bring Earth and space science programs to students, particularly those from K-8. Through partnerships with the Libraries of Eastern Oregon and the Oregon Department of Education, we began establishing video-conferencing connections in schools and libraries

in rural parts of the state. We have invested in professional development for K–8 teachers and librarians, community programs in science and technology, telecommunications infrastructure, and delivery of science and space science programs electronically and in-person to life-long learners of all ages. We have also worked to develop our own curriculum focusing on issues of particular interest to students in the Pacific Northwest, and have worked to get scientists into the schools, in person and via video-conference links, to provide rural schools with advantages they would otherwise not see.

In 2006, approximately one million people enjoyed OMSI's innovative science education opportunities. In addition to a team of motivated and experienced science educators and demonstrators, OMSI employs a team of highly skilled and qualified exhibit and program developers, designers, evaluators, and fabricators.

OMSI is a leader in innovative science education and is always looking for opportunities to captivate our patrons' attention and to provide immersive, hands-on experiences. Nanotechnology is an important component of OMSI's educational mission in inspiring, informing, and exposing our visitors to cutting-edge scientific research. The *Nanotechnology in the Schools Act* will help OMSI accomplish its goals, and we strongly support the bill.

I would like to respond to the questions you raised in your invitation to testify at this hearing. In the process, I believe it will become clear how helpful this legislation is to us and to other science museums.

1) Please describe the nanoscale science and engineering educational activities the Oregon Museum of Science and Industry (OMSI) is engaged in and OMSI's role in the Nanoscale Informal Science Education Network.

As a member of the Nanoscale Informal Science Education Network (NISE-Net), OMSI is active in the development of exhibits and programs designed to inform the general public on the topic of nanoscale science and engineering. OMSI is also participating in the network's effort to develop recruitment and distribution plans to provide exhibits, programs, and professional development on nanotechnology to science museums across the United States.

NISE-Net, currently beginning its third year, has as its goal to create a functioning network of 100 science and technology centers across the United States working together to present the nature and potential impacts of nanoscale science and engineering. This is a powerful vision and it is the largest collective effort across the field of science and technology centers to advance knowledge and understanding of a specific topic—nanotechnology.

OMSI is one often working partners on the NSF grant funded project under the leadership of the Museum of Science-Boston, The Exploratorium, and the Science Museum of Minnesota. Because the general public knows very little about nanoscale science and its applications, OMSI's approach, consistent with the other working partners of NISE-Net, is to present nanoscale science and technology in a way that inspires wonder and motivates the user to seek more depth and understanding of the topic. As experiences within a science museum are largely self-directed and free choice—that is, museum guests move at their own pace, follow their own interests, and build on their prior knowledge—successful exhibits and programs must have a balanced mix of educational content and attracting or motivational elements. Evaluation and museum visitor studies of the work performed by NISE-Net members indicate success in creating engaging experiences for the museum audience that build awareness of and provide context for science and engineering at the nanoscale.

One innovative area of focus of OMSI and the NISE-Net is in the development of nanotechnology forums where participants are encouraged to discuss important economic, social, environmental, and ethical issues regarding emerging nanotechnologies. By creating an atmosphere where experts and lay persons can come together in conversation, a greater understanding of the social and scientific context for nanotechnology can be achieved. Two of these nanotechnology forums were held as part of OMSI's Science Pub series at which science is discussed in the informal setting of a local restaurant. Additional forums were held in Eugene and La Grande, Oregon, creating opportunity for people around the state to join in the discussion.

2) Would H.R. 2436, the Nanotechnology in the Schools Act, be a beneficial resource for informal science education institutions? What priority should it be given relative to other kinds of support for informal science education activities? How would science museums integrate advanced equipment into their educational activities?

H.R. 2436 will provide needed resources, educational materials, and professional development to assist informal science education institutions in presenting the concepts of nanotechnology to their audiences. Science and Technology centers are motivated to present emerging and cutting-edge concepts in science and technology. It is inherent in our missions to strive to present the latest advancements and breakthroughs. Typically such concepts can be difficult to present to museum audiences—information and educational materials may not readily be available to the museum educator and exhibits and programs that have been tested and shown to be effective at communicating intended educational messages may not exist. Additionally, science museums are challenged by the wide demographic of people that visit. The level of knowledge and awareness on any particular science topic varies greatly among visitors. This challenge is amplified when referring to cutting-edge topics. Often the approach of the science museum is to provide context and background information to help museum visitors begin to develop a conceptual framework of emerging concepts.

The NISE-Net research has shown that most people who visit science museums know very little about nanotechnology. The concept of the scale involved alone is beyond the grasp of even many practicing scientists and engineers—as well as most museum education staff. H.R. 2436 provides resources for educational materials and training specific to nanotechnology. Without this type of support, it would be difficult for museums to introduce these concepts. However, once awareness and knowledge are established, it is more likely the museums will continue to maintain and increase coverage of the topic.

There is great need in the informal science industry for educational tools and equipment designed specifically for informal science learners. It is only recently that tools and equipment in the forms of exhibits, simulations, and educational props on the subject of nanotechnology have been developed and tested with museum educators and museum visitors. Nano is a difficult and abstract topic to tackle in the informal setting. Additional resources are needed to help our field advance new methods for creating context and relevance for our audiences.

3) What types of professional development opportunities are available to informal science educators? What types of programs would need to exist to ensure that these educators understand both the scientific concepts, as well as the equipment?

Professional development opportunities for Informal Science Education interpretive staff are not common in the science museum field. Where they do exist, they are typically in the form of institution specific programs, which often focus on content rather than interpretive skills. Professional development opportunities are available to science museum educators through Association of Science-Technology Centers (ASTC) sponsored programs that provide a forum for museum professionals to network, to expand their knowledge base, and to identify resources. However, relatively few science centers have the resources to provide these opportunities to their museum education staff. Cross-institutional programs also exist, such as the Exploratorium led ExNet and the Fort Worth Museum of Science and History led TexNet, which provide staff training as part of an exhibit rental program. Government agencies, such as NASA and NOAA, offer workshops, and the National Parks Service offers interpretive training, to name a few. Largely, opportunities for professional development are based on specific projects with associated funding opportunities. Nonetheless, these opportunities are rare in the field.

OMSI's research indicates that science centers value this training. In 2006, OMSI surveyed interpretive staff managers at 57 large science centers around the country. Eighty-nine percent of respondents indicated that they consider "exhibit content training" to be either "extremely valuable" or "very valuable."

In addition, research strongly indicates the value of skilled interpreters in enhancing the visitor's experience and learning in science exhibitions: "live interpretation can support a wider range of visitors and encourage social learning behaviors," especially when facilitators are trained to promote constructivist [the active building of knowledge and skills], self-directed learning (Marino and Koke, 2003).

Programs for ISE staff should be based on best practices and research on adult learning and successful professional development models (e.g., Ingvarson et al., 2005; Morrow, 2004; Loucks-Horsley et al., 2003; National Resource Council, 1996a, 1996b; Cunningham, 2004).

Based on a review of the relevant literature, OMSI identified five characteristics common to successful professional development;

- continuously improves based on evaluations of visitor teaming/experience
- creates structure for long-term support and continued learning opportunities

- is based on current learning theory/best practices
- teaches content, pedagogy, and the skills to apply this knowledge
- involves active participation by trainees during development, implementation, and evaluation.

Providing for the training of museum staff regarding the nature of and issues related to nanotechnology is an important element to the success of nanotechnology education in museums. To this end, availability of effective training materials and access to science experts are critical. Innovative to H.R. 2436 is the potential for focused professional development for museum educators on the use of proven educational materials and exhibits on nanotechnology. OMSI would encourage the development of user communities—possibly in connection with NISE-Net—that would provide connections across the science museum education field for sharing outcomes and improvements based on experiences and best practices in the use of proven educational tools and techniques.

4) How do informal science education centers decide which subject matter they will focus on? What resources do they use to help create exhibits and programming that matches content to the knowledge level and interest of the audience?

OMSI's process for the selection of educational topics to feature in the museum is based on input from museum visitors and science education experts—including science researchers, classroom science teachers, university professors, and science museum educators. This input informs the museum both on what the public wants to learn about and what science academia believes is important for the general public to know. Content and educational approaches are informed also by the relevant national and state science standards and benchmarks. This approach is similar to the approach of many science museums in the field.

In particular, OMSI typically conducts front-end research with visitors to the museum in advance of selecting or developing a topic. Through visitor surveys, in-depth interviews, and focus group studies, we begin to develop a profile of what people generally know on a topic, what their interests are, and what are likely to be effective points of entry into a topic.

Museum visitor research and evaluation continues through the development of exhibits and programs in the form of prototype testing. During this phase of development, early mock-ups of planned exhibits or programs are presented to a cross-section of museum visitors to begin to assess how effective the strategies are in communicating intended educational messages, how engaging the experiences are, and how intuitive, or easy to use or grasp, the activities are. Also during this phase, expert advisors and content specialists inform the accuracy of content and advocate for alignment with research and science standards—they help the development team figure out what is important to communicate.

As part of this ongoing process, OMSI has determined that nanotechnology is an important subject for our visitors to understand. This is partly because of the rapid rise in nanotechnology's relevance to the rest of the scientific world. In addition, it reflects our surroundings in the Portland area, where major electronics companies like Intel are operating at the nanoscale every day.

The front-end work within the VISE Net has shown that less than half of the adult population of the United States has heard of nanotechnology and less than 20 percent can provide some level of basic definition. However, the studies also show that the general public is interested in the topic and possesses a positive sense about nanotechnology.

5) Do science museums have resources to maintain advanced equipment?

Commonly, science museums come in three varieties: large, medium, and small—defined by size of budget, physical size, and number of staff. In general, the larger institutions in the science museum field will have full-time technical support staff to repair and maintain advanced equipment. Smaller institutions will not. Through user communities, there is a potential for smaller institutions to partner with other science museums, school districts, or other entities increasing their capacity to afford and maintain advanced equipment and provide advantages they would not normally be able to obtain on their own.

Regardless, it is important that materials for use in museum programs and exhibits be designed for and tested in the science museum setting. As a result of science museums striving to engage visitors by involving them directly in the activity or phenomenon being presented, it is necessary that exhibits and educational props and materials be engineered for repeat use by an inexpert audience. They must be designed for durability, low or easy maintenance, and intuitive or ease of use. It

may not be the case that equipment or materials designed for use in research facilities can be used straight out of the box on the museum floor—museum exhibit and program, developers, designers, and fabricators recognize the unique environment of the science museum and this knowledge informs the design of successful museum experiences.

It is worth mentioning that technology advances, specifically in electronics and computers, have made it possible to successfully create higher technology experiences that nonetheless are considered to be durable and low maintenance in the museum environment—and therefore accessible to all science museums. Assuming the intent of the *Nanotechnology in the Schools Act* is geared toward durable and low maintenance equipment, I might suggest that a maintenance provision be added to the bill to better enable institutions to take advantage of new and advanced equipment.

In conclusion, I would once again like to thank the Subcommittee for your attention to this important issue. Our future as a nation of discoverers, inventors, and innovators depends on education and inspiration. I believe that the *Nanotechnology in the Schools Act* will help ensure that our scientific future stays bright, and I look forward to the opportunity to take advantage of this program.

BIOGRAPHY FOR RAY VANDIVER

Dr. Ray Vandiver is the Vice President of New Project Development for the Oregon Museum of Science and Industry (OMSI). He is the principal department head responsible for the development, design, fabrication, and maintenance of OMSI's public exhibitions and programs. Dr. Vandiver received his Ph.D. in Atomic and Molecular physics from the University of Missouri-Rolla. He has been involved in informal science education for the past 17 years. Early in his career, Ray founded the Bootheel Youth Museum—a hands-on museum for rural Southeast Missouri. Ray has been the recipient of several grant awards in the field of informal science education from the National Science Foundation and NASA and has been invited to sit on numerous panels as a representative of the science museum field including the NSF, National Institutes of Health, and National Academies Committee on Assessing Technological Literacy.

The Oregon Museum of Science and Industry (OMSI) is a non-profit, independent, scientific, educational, and cultural resource center dedicated to improving the public's understanding of science and technology. Founded in 1944, OMSI is considered one of the top ten science centers in the United States and has earned an international reputation in science education. Its facilities include a 219,000-square-foot museum featuring five exhibit halls, eight hands-on public labs, a planetarium, an OMNIMAX theater, and the USS *Blueback* submarine. OMSI also offers a wide range of educational and outreach programming, including residential camps, summer classes, museum camp-ins, after-school science clubs, and traveling programs that deliver hands-on experiences to communities throughout Oregon and six other western states. In addition, OMSI provides professional development opportunities for K–12 teachers, including workshops, a science teaching resource center, and distance-learning programs targeted at educators in rural communities. In 2006, approximately one million people enjoyed OMSI's innovative science education opportunities. In addition to a team of motivated and experienced science educators and demonstrators, OMSI employs a team of highly skilled and qualified exhibit and program developers, designers, evaluators, and fabricators.

Chairman BAIRD. Thank you, Doctor. We have been joined by Dr. Dan Lipinski.

Mr. Murdock.

STATEMENT OF MR. SEAN MURDOCK, EXECUTIVE DIRECTOR, NANOBUSINESS ALLIANCE

Mr. MURDOCK. I would like to thank you, Chairman Baird, Ranking Member Ehlers, and the Members of the House Subcommittee on Research and Science Education for the opportunity to testify on a topic of increasing importance to my membership, which is the need to insure a talented and growing nanotechnology workforce in this nation.

I would also like to thank Congresswoman Hooley and Congressman Lipinski and all the other co-sponsors of this important legislation.

My name is Sean Murdock. I am the Executive Director of the NanoBusiness Alliance. We are the primary policy and advocacy organization for the entrepreneurs and innovators working to commercialize nanoscience innovations in America, working to translate fundamental breakthroughs that have been created through the Federal Government's investment in nanoscience into real-world products and processes that improve our nation's economy, our health, and our quality of life.

This subcommittee and the Science and Technology Committee in general have long recognized the importance of nanotechnology. Nanotechnology is a new way of making things that bridges traditional disciplines like biology, chemistry, physics, and material science. From a business and commercial perspective, nanotechnology is really the frontier of science-based innovation. It is increasingly being viewed as the tool kit that businesses will need to draw upon to remain competitive in the 21st century.

As you know, there is a global race for leadership that is well under way. This committee got us off to a fantastic, wonderful running start with the *21st Century Nanotechnology Research and Development Act*, a very important piece of legislation, which will be coming up for reauthorization, and put us well on our course. Recently other countries around the globe have elevated their commitments as well, in particular, Europe with the 7th framework, and now Russia. I brought with me some news that Russia has committed \$5.1 billion to nanoscience research from the oil windfall that they have. There is a story in the Financial Times yesterday.

So this is a global competition that is getting increasingly competitive. And folks are focused on the research. But we must not only lead in the fundamental research. We have to lead in the translation of that research into new products to make us competitive, that employ people, and that do improve the quality of life.

In order to do that we need to have a world-class work force, and there has long been recognition of *The Gathering Storm*, and I certainly don't need to tell this committee about the dynamics of the need for technologically-proficient scientists and engineers.

However, what I do want to impart is that this is not just a long-term problem. We need to be thinking about solving this and taking significant steps to address it today. Already nanotech companies throughout the country are finding it difficult to attract and retain the talent that they need. It is a common topic of conversation amongst the membership.

And it is particularly acute in some of the areas that don't have well-developed tech-hubs, you know, as Silicon Valley and Boston do, but in the Midwest where I am from, from Chicago, and while H1B provides a temporary solution, it is just that. We all recognize that we need to get ahead of the curve.

That is going to be less and less effective moving forward as the opportunities grow throughout the world, and the world becomes flatter. Folks will be less likely to stay here, and we are going to see more and more of that talent that we educate be repatriated.

So when you look at reasonable growth assumptions for what will happen with the nanotech sector, and frankly science and technology capabilities going forward, we are going to need to take action now to start bridging that gap.

We are quite excited about this legislation. I think it is important to note that this does not try to impose anything. It is not imposing the use of the equipment, nor is it imposing the adoption of curriculum. What it is doing is empowering. It is empowering world class, committed, capable science teachers in high schools, community college, and at the university level to make use of this technology to inspire the next generation of scientists and entrepreneurs.

And I believe Thomas Edison once said that, "Genius is one percent inspiration and 99 percent perspiration." It is important to recognize that without the inspiration, no one undertakes the perspiration, and this is an incredibly important opportunity to really inspire the students throughout the country.

So in closing I think it is incredibly important that we provide these kind of programs that allow our best and brightest wherever they may be, in high-need schools and in low-need schools, throughout the country to reach their full potential because we need to in order to compete in the future.

[The prepared statement of Mr. Murdock follows:]

PREPARED STATEMENT OF SEAN MURDOCK

I would like to thank you, Chairman Baird, Ranking Member Ehlers, and Members of the House Subcommittee on Research and Science Education, for the opportunity to testify on a topic of increasing interest to my membership: the need to ensure a steady and growing nanotechnology workforce in America. I would also like to thank Congresswoman Hooley, along with her co-sponsors, for introducing this important legislation.

My name is Sean Murdock, and I am the Executive Director of the NanoBusiness Alliance. The NanoBusiness Alliance is the nanotechnology industry association and the premier nanotechnology policy and commercialization advocacy group in the United States. NanoBusiness Alliance members span multiple stakeholder groups and traditional industrial sectors, including newly formed start-ups, Fortune 500 companies, academic research institutions, and public-private partnerships working to derive economic development and growth through nanotechnology. This wide group of stakeholders has come together because we believe that nanotechnology will be one of the key drivers of quality-of-life improvements, economic growth and business success in the 21st century. The Alliance provides a collective voice and a vehicle for efforts to advance the benefits of nanotechnology across our economy and society.

This subcommittee, and the Science and Technology Committee in general, have long recognized the importance of nanotechnology. Nanotechnology is a new way of making things that bridges traditional disciplines like physics, chemistry, biology, and materials science. From a business and commercial perspective, nanotechnology is the frontier of science based innovation. It is the new tool kit that companies will need to draw upon to remain competitive in the 21st century.

As you know, a global nanotechnology race is well underway. China, Japan, the EU, India, Russia (which recently announced public nanotechnology research funding of \$1.8 billion per year, exceeding U.S. funding), and other nations have made substantial commitments of public funds in order to establish preeminence in nano-related research and development, with the recognition that preeminence in R&D will drive economic growth and enhance national security. The United States has made a strong start in this race, and the *21st Century Nanotechnology Research and Development Act* had a lot to do with that. This subcommittee will be reauthorizing that landmark legislation soon, which is an important task.

While the *21st Century Nanotechnology Research and Development Act* focuses on the research side of this subcommittee's jurisdiction, the Science Education side is just as important. We cannot realize the potential of our federal research and devel-

opment investments without a robust, scientifically and technically proficient workforce that understands the unique challenges and opportunities of nanotechnology. The bill under consideration is designed to create such a workforce.

America's universities increasingly rely on foreign students to fill their science and engineering programs, and those foreign students tend to go home to their host countries after they receive their degrees—in fact, they are required to do so. Once home, they enter the workforce and compete with American workers and American companies.

This is especially true in the case of nanotechnology. At the graduate level, the United States boasts some of the best nanotechnology education in the world, so foreign students are especially attracted. At the same time, the high rate of nanotechnology investment by foreign companies pulls those foreign students just as strongly back to their homes. We are currently creating our competitors' workforce.

Instead, we should be creating the next generation of American scientists and engineers, all armed with the understanding of nanotechnology that will be a prerequisite for technological leadership in their lifetimes. We do that in three ways:

- Get students excited about science;
- Start them on the right educational path earlier; and
- Provide them with the learning opportunities they need.

Getting students excited about science is the first step because it is the most fundamental. Thomas Edison once said, "Genius is one percent inspiration and ninety-nine percent perspiration." But, the inspiration must come first. Without it, students will choose other careers, as we have witnessed over the past decades. If students are not inspired to become scientists, fancy labs or years of required courses will not matter. Hands-on nanotechnology truly has the potential to inspire our future workforce. Exploring the nanoscale, seeing the hairs in a fruit fly's compound eye, watching nanodots light up in different colors depending on their size, and manipulating the fundamental building blocks of matter—these are what grab the attention and interest of young people and make them want to do more.

Once we have their attention, we need to put our students on the right educational path. We cannot expect to have American graduate students pushing the frontier of interdisciplinary nanoscience unless we have American undergraduate students—and even high school students—developing a basic understanding of nanoscience. We need to push nanoscience as far down the educational pyramid as possible, just like we have done with biotechnology. The earlier a student starts, the farther he or she can get.

As a nation, we have a strong history of responding quickly and effectively to provide the learning opportunities our students need. The most famous example is the aftermath of Sputnik, when Congress passed the *National Defense Education Act* which enabled schools throughout the country to purchase microscopes and other state-of-the-art equipment. Today, although there is no single Sputnik-like event to focus our national attention, the technological competition is stronger than ever. We need to give our students the opportunities they need in order to be successful and maintain American technological leadership in this fundamental field.

The *Nanotechnology in the Schools Act* is an important bill because it simply and efficiently addresses each of these requirements. By making it possible for high schools and colleges to afford basic nanotechnology tools for classroom use, the bill will help create the next generation of American scientists and engineers. It will get students excited about science. It will enable them to start "doing nanotechnology" in high school, so that they are ready for advanced work in college and graduate school. And it will provide hands-on nanotechnology learning experiences throughout the Nation.

I would like to make two related points about this bill. The first is that it includes facilities such as science museums in the grant program. This provision will do even more to excite young people about science and nanotechnology, because they will be able to try hands-on nanotechnology in a place like OMSI or the Smithsonian Museum of Natural History. The second is that it includes two-year colleges. This provision will help develop a workforce of technicians—already in high demand as nanotechnology businesses look for people who can run their tools.

It is easy to forget that, as the field of nanotechnology expands, we will need more and more people with high-quality vocational and technical education. For every Ph.D. with a breakthrough idea, we will need many people who can turn that idea into a product. As nanotechnology moves from the lab to the factory, the ratio of technicians to Ph.D.s will only increase. These will be good jobs, and we need to

be able to fill them with well-prepared Americans. If we cannot, those jobs will go overseas.

The members of the NanoBusiness Alliance are mostly small companies. The people who lead those companies are the pioneers of nanotechnology, and they want to pass on their knowledge and their passion to a new generation. Our members do what they can through internships and similar programs, but because they are such small operations there is only so much they can do. The *Nanotechnology in the Schools Act* can have a tremendous impact—one that, over time, can reach millions of young Americans.

Again, I would like to thank you for the opportunity to testify in support of this bill. I am happy to answer any questions that you may have.

Chairman BAIRD. Mr. Murdock, thank you.
Dr. Wheeler.

**STATEMENT OF DR. GERALD WHEELER, EXECUTIVE
DIRECTOR, NATIONAL SCIENCE TEACHERS' ASSOCIATION**

Dr. WHEELER. Step number one: Learn how to use the microphone.

I would like to thank you for the opportunity to present this testimony on behalf of the National Science Teachers' Association. My name is Jerry Wheeler. For the last 12 years I have served as the Executive Director of NSTA. I started my career as a high school physics and chemistry teacher and then went on to get a Ph.D. in nuclear physics, and early on in my university research career I got bitten by the teaching bug, and I went back. But I ended up at the National Science Teachers' Association.

Mr. Chairman, while we understand the importance of nanotechnology, and you have heard that testimony, and its application to a wide range of technologies, and the importance of introducing nanotechnology to our students, we do have concerns about H.R. 2436.

In light of the many challenges we face in science education, we believe this legislation places inappropriate attention and emphasis on nanotechnology at the high school level. I would like to bring five points to your attention concerning, again, high school. I am not talking about the other domains.

First, we believe the legislation does not recognize the serious concerns about high school lab exercises and experiences raised by the National Academy of Sciences report, America's Lab Report, Investigations in High School Science. The NAS report found that in the vast majority of schools there is a lack of agreement of how to define the high school lab, on the goals of the lab experience, and it also found, again, in the vast majority of the schools, many teachers are not prepared to even lead the lab, high school science lab.

In an e-mail survey that NSTA did this past March I think further illustrates the points, and my written testimony I have added a lot more of these, and so these are just indicative. I am only picking two short things.

We asked teachers in science to describe their problems of the lab experiences in their schools. "Dear NSTA, I have no specific safe area in which to conduct labs. My yearly budget is the same as it was 12 years ago. I must purchase all my own equipment and supplies. I have no safety equipment other than a portable eye wash station and a fire extinguisher."

One more quote and then I will go on. "Dear NSTA, my high school building was built in 1970. The budget for yearly supplies has not changed in the six years I have been here. I have a supply budget of \$750 a year. I teach between three and four science subjects per year, seven classes per day, two of them being chemistry and physics. I have absolutely no supplies to teach electricity or magnetism or optics."

Mr. Chairman, it is clear the biggest need is not for high-tech specialized equipment in the classroom. Many high schools' labs are in desperate need of facilities, basic equipment, and teacher training to simply teach physics, chemistry, and biology. Teachers need basic solid equipment and more of it.

The second point I want to make to you today is the limited role that the high-tech equipment in high schools play. Most teachers would have limited use of the electron microscope in their schools. It might be valuable to select schools with cutting-edge science fair projects or schools where Intel talent search is encouraged. That would be a very valuable experience for that small number of students. But we question how many labs could realistically be structured around nanotechnology.

There are space limitations, safety limitations, training and service limitations, budget limitations, and curriculum limitations, that all hinder the full use of specialized equipment in most schools. The training to incorporate the use of this equipment into the curriculum and the training to use and maintain the high-tech equipment almost nullify any hope of seriously implementing them into secondary schools. The vast majority of the teachers would be unable to service or repair these instruments.

Fourth, nanotechnology is not tied to any existing content standards. Many high school teachers have a pre-determined number of topics to cover in the short time allocated for science and lab. For the most part when teachers enter this new experience to students, the curriculum they use must be mapped onto learning outcomes that are defined in their state content standards. This is especially true in this time of No Child Left Behind, and this is the year when the science assessment begins.

Given the research on student misconceptions and poor scores that we are experiencing on NAEP and the international tests, focusing on nanotechnology may result in under-prepared teachers doing a lot of hand waving rather than focusing on the instruction of fundamental science.

Fifth and final point, Mr. Chairman and Subcommittee Members, science must be for all. As noted earlier, grants for nanotechnology equipment will undoubtedly benefit the schools that already have strong AP programs in affluent neighborhoods. But there are far too many high-risk schools with limited lab resources. Still fewer qualified science teachers. These needs must be addressed first so that science truly can be for all.

In closing, Mr. Chairman, there are a number of critical needs in science education that can and must be addressed by federal programs. These needs have been identified in the report we are all familiar with, *"Rising Above the Gathering Storm"* or the *"Augustine Report,"* and it has been raised repeatedly in hearings before this subcommittee and in the Senate. With so many challenges

to the current high school lab sciences and science education in general, the National Science Teachers' Association does not believe that legislation that would authorize \$15 million to "strengthen the capacity of the United States secondary schools to prepare students for careers in nanotechnology," is the best use of our limited federal funds.

NSTA would prefer that the grant funds be provided so that labs could be able to purchase basic equipment and supplies so that every high school lab will have enough basic microscopes so that every child could use a microscope rather than two or three students on one.

Grant funds should also be used for more highly-qualified teacher training in lab science. I assume that is not for me, but I see the red light, so I will stop, and I will be available for answering questions.

[The prepared statement of Dr. Wheeler follows:]

PREPARED STATEMENT OF GERALD WHEELER

Mr. Chairman and Members of the Committee,

Thank you for this opportunity to present testimony on behalf of the National Science Teachers Association. My name is Gerry Wheeler and for the last 12 years I have served as Executive Director of the National Science Teachers Association.

The National Science Teachers Association is committed to promoting excellence and innovation in science teaching and learning for all. We offer members a wide variety of resources and support, including high quality professional development, publications, networking opportunities, and curriculum materials. The majority of our members are high school teachers and supervisors responsible for the lab experiences of hundreds of thousands of students every year.

Mr. Chairman, NSTA has been privileged to provide testimony on a number of key issues before this committee in support of very valuable initiatives, such as the Partnerships for Laboratory Access bill, and federal programs available to K-12 STEM. We thank you for again inviting us to speak to this important issue of labs and nanotechnology.

While we understand the importance of nanotechnology and its application for a wide range of technologies, and the importance of introducing nanotechnology to our students, we have serious concerns about H.R. 2436, the *Nanotechnology in the Schools Act*. In light of the many challenges we face in science education, we believe this legislation places inappropriate attention and emphasis on nanotechnology at the high school level. I would like to bring five key points to your attention.

First, we believe this legislation does not recognize the serious concerns about high school laboratory experiences raised in the National Academy of Sciences report *America's Lab Report: Investigations in High School Science* and other key federal reports.

The NAS report found that in the vast majority of schools, which includes schools with AP and IP programs, there is a lack of agreement on how to define high school science laboratories and a defined lack of consensus on the goals of laboratory experiences.

The report also found that many teachers are not well prepared to lead high school labs. There is a lack of effective undergraduate laboratory experiences for future teachers. Further, there is a lack of comprehensive systems of support at the school, district, and state levels for high school laboratory experiences.

Laboratory science is a high-priced luxury beyond the reach of far too many public high schools, especially high need schools. A 1995 report from the U.S. General Accounting Office titled *School Facilities: America's Schools Not Designed or Equipped for the 21st Century*, found that 42 percent of all schools surveyed nationally reported that they were **not well at all** equipped in the area of laboratory science. In addition the report found that:

- 43 states reported that one-third or more of their schools met functional requirements for laboratory science **not well at all**.
- 49 percent of schools with a minority student population greater than 50 percent reported meeting functional requirements for laboratory science **not well at all**.

- Over 48 percent of schools where 40 percent of the student population qualified for free or reduced lunch reported meeting functional requirements for laboratory science **not at all**.

An e-mail survey we did this past March further illustrates the points made in the NAS lab report. We asked teachers and science supervisors to describe the problems with the lab experience in their school. I have included some of the more representative comments in my written testimony, and would like to share a few comments here today.

- In my urban, inner city school, I teach a lab science in an old business room. There are no tables, benches, water or gas service, sinks, fire extinguisher, eye wash stations, fire blankets, or other equipment. In addition, while there is a high rate of attrition towards the end of the year, each September starts with 50 students in each class.
- I have no specific, safe area in which to conduct labs. My yearly budget is the same as it was 12 years ago. I must purchase all my own equipment and supplies. I have no safety equipment other than a portable eye-wash station and a fire extinguisher. My district claims labs are "extracurricular" and not mandated by my subject. My kids are used to labs using kitchenware or materials purchased at Wal-Mart. They have no idea how to use scientific equipment or even what it looks like due to a lack of funding.
- I have been teaching high school biology for ten years. I have old microscopes that I could swap for coke bottles and not notice a difference. However, the greatest problem I see is my lack of skill in the area of lab investigations. I agree that this is the best source of learning that my kids can get; I just simply do not have the skill to design these labs. IF the NSTA wants to make a change in science education, THIS is where it should be done. . . TRAINING.
- My high school building was built in 1970. The budget for yearly supplies has not changed in the six years I have been here. I have a supply budget of \$750 per year. I teach between three and four science subjects per year seven classes per day, two of them being chemistry and physics. I have absolutely no supplies to teach electricity and magnetism or optics. My chemistry supplies are even worse. My lab facilities are set up for physics, but I am expected to teach chemistry in low benches. I don't know a chemist who will use a Bunsen burner sitting down. Hence, I do not teach the labs that require Bunsen burners because I feel it is unsafe to use the burners in my room. I also do not have a ventilation hood in my room.
- We do not have any rooms to use as actual laboratories. Although we have lots of equipment, we have no place to safely use it and few teachers who know how to use it. Currently the one room that had been a lab is used by teachers to sell hot chocolate and nachos to students to raise money for trips to Washington, DC for a very small group of students. . . the lab cannot be used as a lab. . . they removed the lab tables and installed desks for all the students.
- I have not learned how to facilitate real thinking and essential planning for authentic lab experiences. I don't know what students really need in an introductory chemistry experience at the high school level, and I cannot figure out how to teach logical thinking and sequencing to 20+ students in lab at the same time. My time management skills are lacking. There's much more, too.
- I teach chemistry and Earth science in a room with six lab tables; it was originally designed to be a physics lab room. There is electricity to the tables, but it doesn't work. There are not sinks, therefore no eye-washes; there are no gas outlets. The sink at my instructors table has the water turned off and the gas turned off. We were given a budget of \$5,000 for each department last year, but the orders were not filled because. . . who knows? I have not received the supplies I ordered for eight out of the last 10 years. When first took over this class-lab room and associated storeroom, there was a great amount of equipment and glassware and old kits and a little of everything. It is not possible to do any other than the most elementary labs at this school. It would be unsafe and probably criminally liable to attempt most chemistry labs. The fire extinguisher doesn't work.
- While I do not teach high school science currently but do teach in a two-year community college, I see many students entering with virtually no lab experience. While some students come quite prepared, it's very frustrating for me to have students coming into a college biology class with no knowledge of

basic lab equipment and techniques, such as using beakers, graduated cylinders, pipettes, or even basic microscopy skills.

- Our school does not provide enough funding for lab experiments. In addition, senior members of the department do not believe that other than AP students and some honors classes—should have access to lab experiments. Therefore the classes I teach—college bound and special education—have little to no money that goes towards lab science in the Biology classroom. Furthermore, the set up of the classroom also is a problem when it comes time to do lab experiments.
- I teach biology in a portable without any sinks, no storage, and only four outlets. It's such a challenge to put together a real lab. My portable is far away from the real science labs so it's hard to even get materials over here. There's no prep area out here so I have to go to one of the main buildings to prep. Yet those prep rooms are not easily accessed if you don't have an attached classroom. My room has carpet so I am reluctant to use many chemicals because they are difficult to clean up if spilled.
- Our school has minimal funding for improving the quality of lab sciences. Individual teachers are encouraged to write for grants using their own time without pay. Three of our four science rooms do not have eye wash stations or proper venting equipment. There is no interest in funding the purchase of electronic data collection equipment/computer based labs by the administration. Little effort is made in our district to train teachers to improve the quality of lab experiments and the necessary follow-up assessment.

Mr. Chairman, it is clear that the biggest need is not for high tech, specialized equipment in the classroom. Many high school labs are in desperate need for facilities, equipment and teacher training simply to teach chemistry, physics or biology. Teachers need basic, solid equipment—and more of it.

Second, the role of high tech equipment in secondary schools is extremely limited. Most teachers would have limited use for an electron microscope in their schools. It might be of value to select schools where great emphasis and opportunities exist for cutting edge Science Fair projects or where Intel Talent Search type of programs are encouraged. It might have some use in a specialized science magnet school. But we question how many labs could realistically be structured around nanotechnology.

Third, space limitations, safety limitations, training and service limitations, budget limitations, and curriculum limitations all hinder full use of such specialized equipment in most schools. The training to incorporate into the curriculum and the training to use and maintain the high tech equipment alone almost nullify any hope of seriously implementing it into secondary schools. Even if the high tech equipment were donated, the vast majority of teachers would be unable to service and repair these instruments.

Fourth, nanotechnology is not tied to any existing content standards. High school teachers have a number of topics to cover in the short time allotted for science education and labs. For the most part when teachers introduce new experiences to students, these experiences and the curriculum they use must be mapped to the learning outcomes as defined in their state content standards. Given the research on student misconceptions and the poor scores we are experiencing on NAEP and on international tests, focusing on nanotechnology may require under-prepared teachers to do lots of “hand waving” rather than focus on the instruction of the current fundamental sciences.

Fifth, science must be for all. As noted earlier, grants for nanotechnology equipment would undoubtedly benefit schools with already strong AP/IB programs in affluent neighborhoods. There are far too many high-risk schools with limited lab resources, few AP/IB programs, and fewer still qualified science teachers that desperately need assistance to teach even the basic sciences. These needs must be addressed first so that Science truly can be for all.

Mr. Chairman, the Internet can and does provide a host of rich learning experiences for students on nanotechnology. A search on NSTA SciLinks shows a number of rich learning experiences for both students and teachers, sponsored by universities such as Leigh University and Rice University; Foresight, a leading think tank and public interest institute on nanotechnology; Quanteg LLC, a company which focuses on nanotech education and networking; and Technology Research News also provide good resources on this subject. Some of these sites are listed below.

For teachers: All About Nanotechnology

Find the answer to that question and discover additional information on Nanotechnology, what it consists of as well as its current and future impacts on the world of science.

<http://www.livescience.com/nanotechnology/>

Nanotech Now: Tiny Technology All Around You

Scientists who work in the nanotech industry have long promised better products in basic technologies and human health. While many of the applications have yet to leave the lab, nanotech is all around you. Discover some products of nanotechnology.

<http://www.livescience.com/technology/060330-nanotech-now.html>

About Nanotechnology

Here you will find the answers to eleven of the most frequently asked questions about nanotechnology.

<http://www.foresight.org/nano/whatisnano.html>

It's a Small, Small, Small, Small World

Learn the advantages of nanotechnology.

<http://science.howstuffworks.com/framed.htm?parent=nanotechnology.htm> &
url=<http://www.actionbioscienc...>

For students: Nanotechnology in Agriculture and Food Production

What nano-engineered food products will appear on the market over the next year or two? What are the potential benefits and risks? Who will be affected? And how can consumers become engaged early on?

<http://www.pewtrusts.org/pdf/Nanotech-agfood-090406.pdf>

Introduction to Nanotechnology

Discover how the discovery of the bucky ball has helped pave the way for nanoscience research.

<http://www.lehigh.edu/?inimagin/intronano.html>

How Nanotechnology Will Work

In this edition of How Stuff Will Work, you will learn how nanomachines will manufacture products, and what impact nanotechnology will have on various industries in the coming decades.

<http://www.howstuffworks.com/nanotechnology.htm>

Nanokids: Explore

Nanotechnology becomes fun with the adventures of NanoKids™, who materialize after a computer crashes in chemist Jim Tour's lab! Information is fun for the user to learn with and contains basic nanotechnology information.

<http://cohesion.rice.edu/naturalsciences/nanokids/explore.cfm>

Nanotube Memory

This is a news article of the scientific publication of a joint design by two universities for a magnetic nanotube flash memory, which promises to be very compact and fast.

<http://www.trnmag.com/Stories/2005/051805/Nanotube-memory-scheme-is-magnetic-051805.html>

Understanding Nanotechnology

This site gives the past, present, and future of nanotechnology with some palatable science. It may spark attention with some of the nanotechnology in everyday life. A phone interview with a high school class is one article.

<http://www.understandingnano.com/>

Introduction to Nanotechnology

Here you will learn about nanotechnology and what it may bring in the future.

<http://www.nanoword.net/pages/intro.htm>

In closing Mr. Chairman, as clearly identified in the report *Rising Against the Gathering Storm*, and raised repeatedly in Science Committee hearings and in the Senate, there are a number of critical needs in science education that can and must be addressed by federal programs.

With so many challenges to current high school lab science and science education in general, we do not believe that legislation that would authorize \$15 million to "strengthen the capacity of United States secondary schools to prepare students for careers in nanotechnology" is the best use of limited federal funds.

NSTA would prefer that grant funds be provided so that labs could be able to purchase basic equipment and supplies so that EVERY high school lab in America have enough microscopes so that EVERY child could use one rather than two or three students sharing one old microscope.

Grant funds should also be used for more high-quality teacher training. Science teachers don't need more "fun" activities for students. Don't give teachers more pretty toys to play with—toys that don't have a strong base in a fundamental science curriculum tied to standards. Instead, teach them how to structure solid lab experiences and incorporate them into a well-organized and rich science curriculum for students.

I look forward to answering any questions you may have.

BIOGRAPHY FOR GERALD WHEELER

Dr. Gerald Wheeler is the Executive Director of the National Science Teachers Association, the largest science teacher organization in the world. Prior to joining NSTA, Dr. Wheeler was Director of the Science/Math Resource Center and Professor of Physics at Montana State University. He also headed the Public Understanding of Science and Technology Division at the American Association for the Advancement of Science (AAAS) and has served as President of the American Association of Physics Teachers (AAPT).

Since joining the Association in 1995, Dr. Wheeler has overseen the creation of several science education initiatives and resources aimed at strengthening the quality of science teaching and learning. Dr. Wheeler was the driving force behind SciLinks®, a collaborative project with major publishers that links science textbooks to teacher-approved web sites, and Building a Presence for Science, a program that works to identify then connect science education contacts in each school building nationwide and provide them with teaching resources and professional development opportunities. Most recently, Dr. Wheeler was instrumental in the formation of the NSTA Learning Center, the national "home base" for science educators in search of quality content-based professional development and the NSTA New Science Teachers Academy, a professional development program, co-founded by the Amgen Foundation, designed to encourage and support new middle and high school science educators in their first few years of teaching.

For much of his career Dr. Wheeler has played a key role in the development of mass media projects that showcase science for students. He was involved in the creation of 3-2-1 Contact for the Children's Television Workshop, served on advisory boards for the Voyage of the Mimi and the PBS children's series CRO, and created and hosted Sidewalk Science, a television show for young people on CBS-affiliate WCAU-TV in Philadelphia. Dr. Wheeler has co-directed the National Teachers Enhancement Network, an NSF-funded distance learning project offering science and math courses nationwide.

Dr. Wheeler received an undergraduate degree in science education from Boston University and a Master's degree in physics and a Ph.D. in experimental nuclear physics, both from the State University of New York at Stony Brook. Between undergraduate and graduate school, he taught high school physics, chemistry, and physical science.

DISCUSSION

Chairman BAIRD. Thank you very much. We will start instituting buzzers instead of lights, but in that case that just means we are going back into session over at the Capitol Building, but we should have at least a fair bit of time before votes are called.

I will recognize myself for five minutes for questions.

This is, in my judgment, a good hearing, because good hearings you come away from somewhat torn, because there are good arguments made on both sides. I think there is consensus from what I hear that nanotechnology is absolutely important to teach people, that it is clearly something that we need to know now but will even grow in importance in the future.

But at the same time the question is what is the efficacy of this particular legislation vis-à-vis other needs. One of the questions that runs through my head is Dr. Wheeler's point, and we have heard this in this committee before, about people having no lab space or no equipment at all, just even for rudimentary science.

On one hand one could say, well, that should be the priority. On the other hand to be perfectly blunt, \$15 million isn't going to remedy that either. If we took all this proposed \$15 million from the bill that has been described it would be a drop in the bucket on that, to be perfectly honest, at the federal level. Most of that responsibility probably ought to be borne by the local school districts.

Conversely, my question then, though, is how, if we were to authorize this bill and put forward the \$15 million, how can you scale up nanoscale research? How can you get this information out beyond the lucky few schools, be it high schools, secondary, or post-secondary schools? How do you get it out there in ways that you couldn't through just computer simulations, or something like that, or just some eloquent graphic illustration of the kind of things we have here? How do you do that, and I am open to that question. That is the question. Where, how do you do it, and where do we get the bang for the buck if we do that?

I open that to whoever wants to address it.

Dr. WHEELER. I think it was mentioned by two people testifying that, in fact, there are plans for extending distance learning and plans for simulation, use of simulations and models, et cetera, and again, I would concur with you and echo your comments that in no way does NSTA think that nanotechnology isn't important. What we are talking about is what is the appropriate use at this particular stage.

But there is a lot that has occurred with nanotechnology. The one that, I mean, excuse me. With distance learning. The one that comes to mind, Chairman Baird, is the Jason Project in remote access, and that kind of has the best of both worlds. Still pricey, but at least the child, the young learner, gets a chance to get his or her hand on the joystick and do something with it.

Chairman BAIRD. Dr. Fraser.

Dr. FRASER. What we have been doing in Columbus is working with the Columbus City Schools, which are mostly underprivileged, of course. We are working with kids who come to use these new tabletop SEMs and so we can see how best we can work with the schools. We have had the teachers over, and the teachers are excited. I can't think of one who has not been very excited about the possibilities offered by the instruments.

The plan is that we are going to take these SEMs and move them for a week at a time to the schools. Because they are highly transportable, we will prepare the students before the SEMs get there with simulators and leave them with the simulators afterwards on the computers. So that effectively for just a couple of machines we will be able to influence a large number of students that way.

The key thing is, though, and it is quite rightly brought up by Dr. Wheeler, that we have to prepare modules so that the teachers can teach the stuff, and it has to fit into their lesson plan. So we can't just go to professors and say, you should do this, because that is not going to work. But working together with the teachers, they know where they can fit things in and where they could enhance their teaching. The students themselves are taught a great deal about that by working with the equipment and saying, oh, if we were to do this or if we were to do that.

So I think it is about working together. I view that part of this bill involves the preparation of modules to help the teachers, and the students, to use the equipment and then have the equipment go around to school districts in that way. So I think it can be quite effective for, well, compared with our research funding, quite effective in terms of the size of funding.

Chairman BAIRD. They could do something away from the machinery so to speak.

Dr. FRASER. Absolutely. They could do it at home.

Chairman BAIRD. And then when it becomes available, then you execute that during the week in which it is at your school or the few days it is at your school.

Dr. FRASER. They could put their own samples in then. Before that they would have samples that we would have essentially imaged for them, but the simulator works as though they are at the microscope. It is a very, very useful simulator.

Chairman BAIRD. So the combination of the simulation plus—

Dr. FRASER. Yes.

Chairman BAIRD.—the occasional hands-on opportunity is what you see as the benefit, and that is where you get the scaling of it.

Dr. FRASER. And what you would want, of course, is the machines in every school obviously, but if you can't do that, then I think this is a very effective alternative.

Chairman BAIRD. Dr. Ganguly.

Dr. GANGULY. I would just like to add to that.

Chairman BAIRD. Please hit the mik button.

Dr. GANGULY. It is, because this is just a tool, and if we are comfortable with the teacher training, and actually, we have been talking about that, we will incorporate it. It isn't, this won't take the place of anything. What it will do is it will enhance our method of delivery and will empower our students, because that is what we are trying to do, is we are trying to make them excited about it and to see the leg of a fly or the—in something that they have done, not something that they looked at, not the image that they looked at.

If they were able to do this by punching a couple of buttons and then looking at the leg of the fly, that is, I mean, I cannot tell you how exciting that would be for the students. It would be something that they did themselves. It is not something that somebody did and posted on the computer and they looked at that picture.

So it will empower our students and give them that level of excitement.

Chairman BAIRD. In a way beyond just the simulation.

Dr. GANGULY. Beyond just the simulation.

Chairman BAIRD. Dr. Ucko and the Mr. Murdock, and then we will—

Dr. UCKO. One of the things I think that will help to increase dissemination is the whole aspect of cyber learning, and that is an area that the National Science Foundation is getting increasingly involved in.

There is one study that came out recently that I think speaks exactly to this question, involving high school students who were connected remotely to an atomic force microscope using a nanomanipulator with haptic capabilities so they could actually feel

what it felt like moving the probe across materials. It was a virus that they were studying, and the research they did indicated that the kids learned about the morphology of viruses much more using this technique than they did from the classroom type of teaching.

So I think cyber learning offers a way to make these kinds of equipment more widely available to basically anybody with computer access. If they have a haptic interface, such as for this nanomanipulator, that would be even better.

Chairman BAIRD. Mr. Murdock.

Mr. MURDOCK. If I could talk about the human factors rather than the technology for a minute, and to borrow a term from nanotechnology, I think this can do it from the bottom up. I think it is a novel approach to create a significant incentive for those, you know, world class, driven, capable teachers to go and go to the NCLT, for example, and do the research experience for teachers and develop that greater understanding of the body of knowledge and to bring that back to the classroom and to become agents of change, if you will. You know, to inspire other teachers within their schools as well as within their geographies.

And it can, you know, change the system over time. It will take time. Any solution to our needs will take time, but through those students, and I think that what it does, it creates a distributed leadership network that we can draw upon over time.

Chairman BAIRD. Dr. Ehlers.

Mr. EHLERS. Thank you very much. Several comments, perhaps questions.

First of all, I think the real issue is the high schools because the universities, some of them will have nano equipment ready, some of it may have been passed down from laboratories that have used it.

Also, universities, colleges, and community colleges are already eligible to purchase such equipment under funding from the current National Science Foundation programs.

So I think we are really talking about the high schools. You know, this is something that would be wonderful to have, but I get back to the real world. I spent a good share of my life trying to help teachers in schools, elementary and secondary schools, do a better job of teaching science, and I would have to agree with Dr. Wheeler, this is wonderful, but you can't ignore the incredible problems that we already have in the schools. In many of the schools you can't even use this properly without doing a lot of other steps as well.

And that is what we have empowered the National Science Foundation, and we are also empowering the Department of Education to work on these issues. First of all, the professional development of teachers, and secondly, through purchase of equipment.

So the question of the bill is do we really need a specialized bill to cover one area when we already have a lot going in more general areas, and we are trying to build up space? If we had an infinite amount of money, no problem. This would be a great bill.

But we don't, and so the question is as I indicated in my opening statement, do we want to do this to help the schools that are really very good, where students already have many advantages, or do we want to try to reach the entire system?

I don't have the answers, but I am just telling you these are some of the problems we face here. Are we really going to allocate money for a rather specialized use for the benefit of a small number of schools which are not high-need schools and students, small, relatively small number of students who are not high-need students.

And I am not saying I don't like it. I am just saying we have some other problems to address here, too. And to optimize the use of the funds.

Now, perhaps the easiest way would just be to put this new program in the Defense Department, and there would be plenty of money to—if you label it properly, there might be plenty of money to accomplish what you are interested in or what the sponsor of the bill is interested in.

But unfortunately that is probably not an option here. So I have just rambled on a bit, but I welcome any comments anyone would have on my concerns that I have expressed. Fire away.

Yes. Dr. Vandiver.

Dr. VANDIVER. I would suggest that as nanotechnology is a very difficult and abstract topic, the challenge is not only with an understanding among the students but among the teachers, and providing resources to those teachers to help their understanding and comfort with the topic. I think we have to be focused and directed as to how we provide our resources, if we, in fact, intend for nanotechnology to be part of our classroom experience.

I think that the context and background in nanotechnology is essential for the beginnings of understanding. So I think providing the resources will help focus attention and understanding among teachers and students in nanotechnology.

Mr. EHLERS. Anyone else? Yes. Mr. Murdock.

Mr. MURDOCK. Thank you very much.

A few thoughts. One, I think it is important that the program makes use of leverage, ties into all the programs that are out there, and I referred to the NCLT earlier and there are many others that I think can effectively coordinate with leverage.

But I think there is also a lot of value in having a well-defined program and clarity and focus. You know, it generates a lot of excitement and awareness, and I don't know the answer to this question, but I am not sure how broadly those programs are used by the folks that would be using this program. And so by creating a new vehicle, having it, you know, very clear and communicating it broadly, I think you might find that participation is, in fact, broadened and that you do reach more of those needy schools in so doing than the alternative path of what is out there today.

As I said, I don't know the answer to the question, but I think it is quite possible that that would happen.

Mr. EHLERS. Under the bill only a quarter of the grant can be used for teacher education, and of course, as I mentioned already, we have other teacher education programs, but those are more broadly based.

I guess I am also concerned, let me also just mention if a school would desire to do that, this is already available and nano equipment would qualify under the PALS Program, which we already

passed as part of the American—so it is not that it can't be done already.

Anyone else want to comment back to my comments?

Okay. Just to wrap it up, a great idea. I taught many years myself, and I was taught, started teaching in an era when lasers were brand new. I made the local newspaper when I got the first laser within 50 miles. It was a great thing in the classroom. Everyone loved it.

But it was hard to build a curriculum around that. We did wonderful things with it and got some interest developed. It almost sounds to me like from some of the comments you have made this is in the same category. This will attract student interest, being something new and groundbreaking. And, again, is it worth the price we are paying here? How would it—and the biggest question frankly is how would it match with other programs that the National Science Foundation already has?

I am certainly not, in despite my negative comments, I am not totally negative. I am just saying we have got to work all this through before we consider passing this bill.

Chairman BAIRD. Thank you, Dr. Ehlers. This Committee benefits tremendously from Dr. Ehlers' science knowledge but also his background as a science teacher and his critical approach to whatever topic is before us. Thank you.

Dr. McNerney.

Mr. MCNERNEY. Thank you, Chairman Baird.

You know, both the Chairman and the Ranking Member have alluded to the limitation of this bill, i.e., the \$15 million. With that amount you really can't touch that many classrooms, but one thing you could do is develop a curriculum that teachers could use and learn from.

If you were to do that, Dr. Ucko, what would you include in that kind of curriculum that would be beneficial to students transferring to job skills or so on? And what would you want to include in that kind of—

Dr. UCKO. I guess what I would say is that we are already developing curriculum in this area through the NCLT and some of the other grants, the Nano-Instructional Materials Development grants that have been funded previously. And what is really part of the challenge is figuring out how do you take this new emerging area and insert it into the curriculum. Do you use it to teach something new? This whole new domain? That is probably very difficult to do.

Perhaps easier would be to teach existing science and technology using nanotechnology as examples because that is already part of the national standards and the testing.

So that is a real issue. How do you take advantage of nanotechnology however you teach it and use it in the curriculum? It is not a trivial issue, and it is really early to answer that question, because the things that we funded are still in their second or third year in most cases, and we don't have the answers yet. There is very little research out there in terms of how do you develop curriculum, what curriculum works, what are the most effective strategies for teaching nanotechnology?

So I guess I would say we need to wait a little bit longer to answer that question.

Mr. MCNERNEY. Thanks. Well, clearly, Dr. Ganguly had sort of indicated one of the priorities is to inspire the kids. You want to inspire them, not just to go into nanotech but to also go and study their math or do the other things that they need to do to be successful when they get to college and move on from there to contribute to the country.

So that would be something that would be a challenge, a huge challenge, and, like I said, it is something we all need to think about.

Dr. Wheeler, one of the things you said the sort of sparked my interest is you mentioned safety. And I know nanotechnology has safety issues. How big of an issue would that be for a classroom, a lab in nanotechnology?

Dr. WHEELER. I don't think that is an issue, Congressman. I mean, there are issues, but I don't think that is a very big one. The issues in terms of that equipment coming into the classroom, and again, forgive me for my nuclear physics background and my age, it doesn't translate as well to nanotechnology.

But I don't think safety is an issue. I think the bigger issues, the points I made, but within that point, the bigger issue would be the maintenance costs, the training of the teachers to keep that equipment active.

If I could take, since I have the microphone, just put a quick answer on your last question, I am not sure that I would invest—and it is a little bit related to Congressman Baird's question earlier on—I am not sure I would invest \$15 million into new curriculum projects, in part because NSF has said they are doing some, but in part because I was a junior in high school when Sputnik went up. The Federal Government has invested a lot in curriculum projects, and we are still in deep trouble right now.

What we have to deal with is the teaching of the science; are the standards clear, does he or she have the training they need, does it align to the assessment, and a new curriculum is, I am afraid, not going to solve the problem we are in right now.

Mr. MCNERNEY. Thank you for that assessment. You know, I have to say Sputnik did inspire me to go into science, so I mean, I don't know if it was the curriculum or if it was the actual threat that we perceived from Sputnik, but I—

Dr. WHEELER. But I didn't play with a rocket after that.

Mr. MCNERNEY. Do you think this high school training could lead to jobs, to actual jobs, Mr. Murdock?

Mr. MURDOCK. Well, I think, obviously downstream. I think that the high school training, and in particular, as I said earlier, what it will do is it will provide the inspiration to undertake the work going forward in the collegiate level and in the postgraduate level to keep more folks into the sciences.

I will tell you a related thing that we at the NanoBusiness Alliance have been working toward launching, and haven't launched yet, we refer to it as the NanoBusiness Talent Program, Total Applied Learning Through Entrepreneurship, and the idea is to get top math and science students in high school into entrepreneurial environments to begin working with and understanding the impact of science, and again, how it relates to the world at large, how it

relates to businesses, to improving quality of life, and you know, frankly, to national competitiveness and security as well.

And so I think there is a very important thing about getting exposure to the importance and the impact of sciences as early as practical into our educational setting, and that will downstream lead to those opportunities.

Mr. MCNERNEY. Thank you.

Mr. EHLERS. Will the gentleman yield?

Mr. MCNERNEY. Yes.

Mr. EHLERS. Very quickly.

Mr. MCNERNEY. I will yield the time that I don't have remaining.

Mr. EHLERS. Okay.

Chairman BAIRD. The Chair will yield.

Mr. EHLERS. Thank you. Just the interplay of two people being influenced to go into science by Sputnik made me feel very old, because when Sputnik went up, I was inspired to go into politics. If we had a government that couldn't even launch a rocket, obviously they needed some scientists here. Thank you.

Chairman BAIRD. Another good thing Sputnik did. One scientist and one politician out of it.

Mr. Neugebauer from Texas.

Mr. NEUGEBAUER. Sputnik? What is that? No, just—the gray hair probably gives me away.

You know, I follow with interest in Texas Tech University in my district has very robust nanotechnology program there, and it is very interesting. In fact, I had an opportunity to tour there a year or so ago. I guess the question is as we hear a lot of people coming and saying we have got to get more of our young people interested in math and science because the industry comes and sees members of Congress and saying, you know, one of the reasons we are outsourcing jobs to other parts of the world is we don't have the folks here to do that. And the reason we are asking for more VISAs for people is to fill that need.

And so, I guess, the question today, one of the questions would be is who is filling the jobs in nanotechnology today?

Somebody want to field that question?

Mr. MURDOCK. Well, I think you have to look at it in terms of the evolution of the technology. Right now with the federal funding, you know, primarily driving through the *21st Century Nanotech R&D Act*, there have been a lot of scientific breakthroughs, and so many of these companies that have been formed are really in the earliest phases, right, they are just transitioning off, you know, university campuses or federal laboratories. And it is really translational research that is taking place.

So it is drawing upon the Ph.D. scientists and engineers, you know, by and large. As a class if you look at my membership, most of them are what I would characterize as the translational research or product development phase as opposed to the manufacturing phase.

And so who is meeting that need right now? It really is the universities, Ph.D.s, and post-docs and the folks that are, you know, trained in that avenue. As it will evolve over time, though, we are going to need, you know, technicians, non-Ph.D. level, you know, Master's and undergraduate level engineers and technically-pro-

ficient folks. And you see that in some of the more mature nanotechnology companies that are moving to the manufacturing phase, that the skill set migrates over time. But all of them need to have some base level of scientific engineering and technological proficiency.

Mr. NEUGEBAUER. I think the other issue that I thought was interesting, and I think in probably more alignment with my thinking is with the computer technology that we have today in simulation and how we are teaching young people today, I mean, how they learn, how young people, I mean, video games and so it is very much an interactive with computers. If it doesn't make sense at least in the initial phases until this industry is a little more robust to generate some curriculum, the other gentleman was saying is based around using some interactive software to stimulate, you know, the interest in that technology. And then the other piece of that is that is more widely distributable. I mean, most every school are working in that direction and has some computer technology available to it, so you get it to more kids to see if their appetite is interested in that area before you go invest a lot of money in equipment to do that.

I thought it was kind of interesting what Dr. Vandiver said, we have a science spectrum in our community and they bring a lot of exhibits and stuff in, and it is regional, probably serves 20, 30 counties in my district because of the rural part of the country. That is certainly the ability to compliment the curriculum that you might put in the schools, where you are letting them to do it in a simulation, then you can pull that resource into where more people can go and actually see and play with, if you want to say, because they all want to play with it obviously.

But I think the underlying question is the role for the Federal Government, or is this something that school districts and communities that want to have economic development entities to, giving their communities an edge? Is that something they should be doing?

Question. Anybody got any answers?

Yes, sir.

Dr. FRASER. I think the intention of the bill is not to fund these instruments at all schools, but it is to spark the whole program so that local districts will start joining in and leverage federal investment. And the federal investment is worthwhile because we as a nation would like to remain globally competitive, and to do that we have to have this workforce that will eventually develop through I believe the use of the instruments and capturing people into science and having them highly motivated. I think that is the idea. It is not for the Federal Government to support the whole program but to kick start it with getting something back from, you know, their dollar investment, which will be the workforce.

Mr. NEUGEBAUER. And the question is, are we far enough along with this curriculum yet to start buying devices, or do we need to get the high school curriculum a little bit further along with the simulation there and see if there is demand? I am new to the political arena. I come from the business world, and before we went out and manufactured a lot of things or developed a lot of lots, we al-

ways wanted to make sure that somebody wanted one when we got them done. And so I guess that is the question.

Dr. Wheeler, do you want to run with that?

Dr. WHEELER. Yes, Congressman. Thank you. And that takes me back to my first point is the National Academy of Science's report said that as a nation we are confused even about the role of our labs. Is it to excite the student because they can move it, is it to teach them the nature of science, is it to have them verify some law of science? And so I would concur with your last comments, except I probably wouldn't stress just curriculum. It is even more fundamental than that: is what the role of the lab within the curriculum and what kinds of other ways within the curriculum or the child's experience can we accomplish the things we want to accomplish?

So I think that that is a very good comment and worth answering carefully.

Chairman BAIRD. Dr. Lipinski.

Mr. LIPINSKI. Thank you, Chairman. You surprised me there. I thought we were going to go to Ms. Hooley there.

I wanted to thank Ms. Hooley for introducing this bill. I have really been convinced that nanotech really is the new industrial revolution. I have been working with Northwestern University, and Mr. Murdock and I have that in common. We are both alums of Northwestern, and I know he is working with a lot of people there in terms of nanotech. Northwestern right now is ranked 5th in the Nation in nanotech, and there have been about 10 spin-off companies that are conducting cutting-edge nanotech research that have come from Northwestern and, you know, they do have the International Institute for Nanotechnology there. So I am very proud as an alum of Northwestern, and also very happy representing part of Chicago, representing the district in the Chicago area and that Chicago area is doing this in Illinois. *Small Times* magazine ranked Illinois 8th in the Nation in nanotech. The University of Illinois also doing some good work on nanotech. There are four centers dedicated to nanotechnology, so it is great to see this all taking off, and I think it is important for all to be looking at science and technology, it has to start with early education.

But I want to ask Mr. Murdock, in the NanoBusiness community, what is the greatest concern when it comes to education right now? Is it at the elementary level, secondary level, or higher education level? I mean, where is the interest focused in the nanotech business community as to where the education has to be, nanotech has to become more priority education or the future of nanotech, what does it rely most upon right now? Which level of education seems to be most important or stands out most in the community?

Mr. MURDOCK. Well, I think right now just by nature of the demands in immediacy, when you look at these companies, they are endeavoring day in and day out to, as I said, to translate this science into real-world products. And so the immediate needs at this stage are in the Ph.D. level. But there is recognition. I think what is incredibly positive about the community and my membership is that they are thinking long-term. There is recognition that that is today's battle, if you will. That is today's challenge and that we, I think there is recognition that the next step, getting the

broader technical workforce is going to be very problematic as you look at, you know, as a company grows, you have the couple founding scientists, and you have a couple Ph.D.s that work on, you know, those companies when they are in the five to 10 people range. But as they grow, getting that next level of talent in there, and you know, I think that is at the Master's and collegiate level, is going to be challenging.

But, you know, it is something that we are going to have to address across all levels over time. I think there is broad recognition that we just simply don't have a large enough technical workforce, and that is why everyone is here all the time looking at the H1B issue, is that folks are looking to import the talent because they are not finding what they need out there today.

Mr. LIPINSKI. Is it more a concern with more basic levels STEM ed rather than, you know, we are looking at nanotech, and we are speaking specifically about nanotech here, but as we all know nanotech covers a lot of different areas. It is a real concern that we just don't have the students, we are not teaching students to even have the basics in engineering, science and math, to be able to even become interested and to do any kind of work that will help in the nanotech field.

Mr. MURDOCK. Let me try to take that. I think there is broad recognition that there is a shortage of STEM ed across the board. I think what is more unique about nanotechnology and what the companies need are folks that are trained in an inter-disciplinary fashion. Think of a T if you will. Broad enough to bridge two disciplines and deep enough to have the capability within one to do something distinctive. And that is kind of the model of, typically, what folks are looking for, and that means you need to have a robust foundation in science and technology, engineering, mathematics across the board to have that breadth and then to be able to go deep.

Mr. LIPINSKI. Anyone else have any? Yes.

Dr. VANDIVER. I still want to make the case that it is about context. I was also inspired by space science and astronomy to go into science, and if I understand correctly, the best radio telescopes looking out are looking at a resolution of about 10 to the eighth, 10 to the ninth meters. Take that the other way and look in, so we are in the same realm, and if you will, it is like a universe within. Just like we discovered, all of the strange behaviors and new concepts looking out, we are discovering those looking in as well, but the context isn't readily available to students.

So the materials are behaving in ways unexpected, and the properties of matter are going against intuition, and you know, I think this is the stuff that inspires, just like cosmology inspired me when I was young, I can see this, if you really understood the context of what science is achieving today, I think you will get that inspiration, and I think that is the context that we are talking about.

Mr. LIPINSKI. Thank you.

Chairman BAIRD. Saving the best for last, the author of the bill, Ms. Hooley.

Ms. HOOLEY. Well, first of all I so appreciate all of our panelists for being here today and their thoughtful presentations.

I am just going to make some comments and then would like some reaction.

It seems to me not too long ago computers were in great big, huge rooms and then we got them into our universities, and then we got them into our high schools, and now every grade schooler has a laptop on their desk. And it wasn't just exclusive for some schools. It is really now generally used in all of our schools.

As far as whether the Federal Government should have a role or not, we have a role in a lot of things. I mean, any time we are talking about an emerging technology that we want to encourage happening, we get involved in it. This committee just passed a significant bill on, to make sure that we have enough science and math teachers, because we don't have enough science and math teachers.

So I look at this piece of legislation really as, and I think a couple of you said this, as an agent of change, as an inspiration, because you have to, first of all, inspire students. They have to get interested. They have to be excited about something. And I think this is exciting. And they have to be inspired if they are going to go into the field of math and science and to teach it.

We did a symposium in Oregon. We have got a collection of universities working on nanotechnology. We did a symposium, and you know, frankly, most people had no clue what nanotechnology was, and if you went out on the street and you talked about nanotechnology, they wouldn't know what it was. Just like they didn't understand or know what computers did and what they were 30 years ago.

I guess I see this as a little piece that adds a little spark to inspire people to become teachers or to go into that field, and it is a small way of saying we think this is going to be one of the industries in our future, and we need to do something with this. And I mean, that is the reason I introduced the bill. I think it has a lot of merit. I think it is a very modest start. I understand that it is going to, you know, not cover that many schools and that many students, but if we get people to at least understand what nanotechnology is all about and some of our students to understand what it is all about and we inspire people to go into math and science, it may help.

So that is, I don't know if you want to respond to any of that, but any of you that would like to respond to those comments. Not really a question.

Dr. GANGULY. I would like to thank you on behalf of all students for introducing the bill, because it will be a powerful tool which will transcend all fields of science. Because it will just, it will let the students get involved, get excited, and be involved in their own learning. That is much more of an empowerment than anything else. They have to be involved in their own learning, and they will be if we have these kinds of tools available to us.

In 30 years time it will be what computers are now.

Ms. HOOLEY. Yeah.

Dr. GANGULY. So, yes, we have to start somewhere.

Ms. HOOLEY. Thank you. Any other comment?

Mr. MURDOCK. If I could just—

Ms. HOOLEY. Yes.

Mr. MURDOCK.—comment briefly. I think you are absolutely right about the inspiration, and we did have Sputnik, and that inspired a whole generation of folks to go into science and technology, and honestly, we haven't had the next Sputnik over the past couple decades. And I think that is a significant part of the erosion, if you will, of the math and science and technology base. It is quite possible that maybe the Russians see that. As I said before, they committed \$5 billion to nanoscience research, which I find to be pretty extraordinary. And they recently announced that. And so maybe it will engender a little bit more of the same response.

But I think the framing of this as a seed program to, you know, kick start a virtuous circle of distributed technology that gets in the hands of the students so that they can be inspired and engage in honestly self-directed learning where they can take control is a neat framework, and I think what I talked earlier, about trying to change, viewing this as a bottom up. I think it is a bottom-up way to empower world class teachers in all schools and students to really become the leaders of tomorrow.

Ms. HOOLEY. Thank you. And I do want to acknowledge, Dr. Wheeler, I understand, I have been in our schools. I visited our schools, and I know how bad some of our labs are and how much help that they need. I look at our community colleges and look at the number of students that are turned away because we don't have the right labs and the right equipment and enough buildings and enough teachers. So, again, we tried to put a program into place to inspire people to go into math and science, and if we can add to that inspiration by some event that is happening, I think that is to everybody's benefit and hopefully then that in turn also helps schools decide that it is really important that we upgrade and try to put some money into our science labs.

Thank you, Mr. Chair.

Chairman BAIRD. I thank the gentlelady and applaud her for her initiative, and as a former teacher I know how much you value the importance of exciting students and getting them interested in the topic. And there is just no substitute for that.

We may do just a couple of remaining questions, and the puzzle for me is, let us suppose we did this. Let us suppose the money were made available. I have been to a number of high schools that have CAD CAM systems, which were once, you know, state of the art, gee whiz things, and now are actually in fairly common in some of our voc ed, career, and tech ed programs.

But what has troubled me a little bit is that some of the exercises I have seen the students doing are: write your name on the computer and then make the CAD system carve your name into a piece of plastic. Okay. So you got a nice nametag with your name on it. I am not sure what they got out of that.

And so my question, obviously there are more intricate and interesting ways to use the CAD System and to make it an educational experience, but as someone who visits every high school in his district every two years, I see amazing things done, and I see wastes of time.

What would each of you say is the most, what would be the key criteria, if you were to say two or three things that you would put on this if the program were to move forward, in terms of using this

money? What would be the most important thing? If the Congress were to decide, yes, Ms. Hooley has it right, nanotech is something we need to invest in, this money will be well spent, what would be the most important things that would have to happen to make sure it was indeed well spent?

And I will just, Dr. Ucko, and then we will work our way to the right and——

Dr. UCKO. I guess I would answer that by saying that it would be part of a well-tested, well-developed program and not just a piece of equipment that is put into a facility. Using development, figuring out what kids need to learn, how is whatever intervention you are doing going to help kids learn, does it build on learning progressions? That is, does it tie into what they already know and take them to the next level of what they need to know? Has it been tested, has professional development been done for teachers to make sure that they know how to properly use whatever this is in the best way? And that it ultimately has an affect that shows up on student assessments.

Dr. GANGULY. That is, I mean, he put it in a nutshell actually, is that, you know, you have to have professional development for the teachers, because we are life-long learners, and we like to learn, but we have to have the opportunity and the chance to learn it. And once we do, we will be able to apply it into our teaching, and then, of course, finally there has to be an assessment for it. But with the professional development we can use this to enhance our teaching.

Dr. FRASER. And obviously I agree with what has been said so far except I think most of the nanotechnology work is done at the graduate level right now. That is at universities, so I think it would be highly effective in the short-term to develop modules in collaboration between high school teachers and faculty.

Dr. VANDIVER. I think part of a competitive grant process where, based on the merits of the proposal, innovative ideas building on best practices could be rewarded and advance the field.

Mr. MURDOCK. I guess two thoughts. One obviously it has to be integrated into professional development. I referred earlier to the research experience teachers that exist in many of the NFS Centers and NCLT that it could be integrated with.

The second, you know, we talk about the curriculum development efforts, and that is, you know, a research enterprise, developing the next curriculum. There is also translational work that has to take place to translate that into a school and a classroom environment, and I think this could be a very elegant way to develop, if you will, a beta group for the translation of that curriculum development, to see how it is going to play in the schools, and frankly to accelerate the development and the translation of the curriculum from the research-driven curriculum to what is going to get in the schools and work.

So it can be part and parcel of making that happen more effectively and more rapidly.

Dr. WHEELER. I think, excuse me, I think Congressman Ehlers kind of hit it on the head when he said something about the high school. And you can even hear it in our comments and your questions, we have all drifted towards the high school. We talk about

the teacher. The fact is the bill is very rich in very good ideas in terms of two-year college, undergraduate, and informal. So I am in that delightful position of saying you really ought to give the money to somebody else.

It would be much more used, it would excite the Nation more. I am being a little bit sophomoric in my comment, but it will excite the Nation a little bit more if there were good, rich experiences where families can go in and see this exciting stuff. It would pump up the two-year college and I would say the undergraduate much more, and what I would do, the same thing we did after Sputnik. I was a customer, but the same thing the country did after Sputnik was it brought teachers into the universities during the summertime, and it increased the university professor, researcher, teacher conversations, and it was extremely exciting. I was a brand new high school physics teacher at that time. Extremely exciting to go to the University of Connecticut, go to Boston University during the summertime and talk to people about some of these new ideas.

So I would say that we have to be very careful as we talk and ask questions of each other that we don't drift to just automatically assuming the high school teacher or school is going to get it. I think the richness of this bill, and I do appreciate the bill and I think the richness lies outside or at least around the corner when you get into the high school.

Chairman BAIRD. Very, very thoughtful answers. Thank you.

Dr. Ehlers.

Mr. EHLERS. I agree. Very good answers and I am not sure what wisdom I can add to it other than for some observation. All the talk about Sputnik makes me feel good because I just finished writing an article which was entitled, "Where Is Sputnik When We Need It?" Because that is what we have here. We need a reawakening of the importance of science.

During my years working with elementary schools and trying to put science programs in before I got into politics, and also visiting a lot of schools now, and when they have something special dealing with science, whether it is a NASA Program on-line or Jason Program, then they want me to come out and participate.

A couple of things have impressed me. Number one is something we haven't talked about here at all. In my experience, and I have a district that is largely urban, the single-most important factor in the success of a student is to have at least one interested and involved parent. If you have that, the school and the teachers have a chance. If you don't have that, it is very, very tough for them.

Second element is the teacher. And you must have a well-trained teacher, and I can't tell you how many, I have seen very few poor teachers. I have seen a lot of teachers who wanted to teach better in math and science, but they never had the proper training in the subject matter or in the methodology.

And I think the most effective use of our money is, first of all, to train the teachers so that they themselves are excited. And then, of course, beyond that you need a good curriculum, and you have to have the money for the equipment. Trying to teach science without equipment is I think quite meaningless. You can do it at the theoretical physics level, but it is kind of backwards to me that we wait until high school and college level to really get students in-

volved in laboratories when the time they really need it is when they are in elementary school. It gets them more excited, gets them more involved. So I am totally in agreement with what you are suggesting.

And Mr. Murdock, you hit it on the nail. We really have to do a better job of developing a scientific core within this country. We can't depend forever on people from other countries.

So we have, it is clear what the problems are. It is relatively clear what the solutions are, whether we decide we have to do nanotech in a small number of schools or a large number or do telescopes or what have you. We just have to do it.

But putting it together in a comprehensive, workable way and above all providing the training for the teachers is crucial to this. And that means some reforms at the university level and the requirements for students, requirements for teachers, the training of teachers, providing adequate equipment, and the schools which I think is one of the most crucial parts. That is why I have been somewhat negative here, because I want to look at the broad picture and see how does this fit into all of this? How can we really get the kids excited, and how can we do two things here, three things actually?

Excite and innervate the future scientists and engineers. That is number one.

Secondly, how can we prepare the kids for the jobs of the future so that they will be able to work in plants that deal with nanotechnology or silicon wafers or what have you?

And thirdly, how can we keep the populous at large excited about these things so they are willing to pay the bills and support this?

So we have a lot of work ahead of us. By we I mean the scientific and engineering community as well. When speaking to scientists and engineers I always encourage them to go out to their kid's school or to their nearest school to their business, volunteer to speak to a classroom about why they like science or why they like engineering, take along some stuff to demonstrate, some gee whiz equipment, invite the kids to come to their lab or if they are field engineers, to come out and see a bridge they are building or what have you.

That is the real way to get the kids involved, hands on, with a lot of things that they normally would never encounter in their lifetime. And I think we have a unique problem today, have had for close to a century. You never had to worry about that in about 1860, to 1880, when 80 percent of the population lived on farms. You learn an awful lot of chemistry, physics, and biology just by living on a farm.

And so a lot of it didn't have to be taught in schools, and today we have to assume they know zero from day one and work from there.

Having pontificated long enough, Mr. Chairman, I yield back.

Chairman BAIRD. Just long enough, though.

Dr. Lipinski, Ms. Hooley, either of you have follow-up questions or comments?

With that I want to thank our panelists for an outstanding and very informative and stimulating series of presentations. Thank

our audience Members and our fellow panelists, and with that the meeting stands adjourned.

Thank you very much. The record will be kept open for two weeks if anyone wishes to add additional comments.

[Whereupon, at 3:40 p.m., the Subcommittee was adjourned.]

Appendix 1:

ANSWERS TO POST-HEARING QUESTIONS

ANSWERS TO POST-HEARING QUESTIONS

Responses by David A. Ucko, Deputy Division Director, Division of Research on Learning in Formal and Informal Settings; Directorate for Education and Human Resources, National Science Foundation

Questions submitted by Chairman Brian Baird

Q1. You suggest in your testimony that the Committee may want to revisit the issue of improving the nano education component of the NNI after NSF has carried out its evaluation of the activities currently underway. What is the timeframe in which we will have this additional information needed to formulate the most effective educational strategies?

A1. Because the NSF-funded projects in nano education in formal and informal settings are still underway, evaluation is formative. These evaluation efforts are designed to produce data that can guide the projects and suggest mid-course corrections and revision. For example, instructional materials being developed for high school students have been pilot-tested in an Advanced Placement chemistry class; formative evaluation revealed that teacher background in the biological aspects of the topics was weak, and as a result, the professional development component was enhanced. Project summative evaluations will be available within the next 12 to 18 months. In addition, the Nanoscale Science and Engineering Education program evaluation now being planned should be completed in about 24 months.

Q2. In your testimony you stated that the total NSF investment to Nano education awards in fiscal year 2007 was \$28 million. How does this number break down among the kinds of activities that you described in your testimony: instructional resources for grades 7–12, two-year and four-year undergraduate programs, informal science programs and outreach associated with nanoscience research centers?

A2. About half of the FY07 funds in nano education were direct investments in new or continuing awards directed at the following audiences: students and teachers in grades 7–12: 43 percent; public (informal science education): 30 percent; undergraduate (two- and four-year) students: 18 percent; graduate: 9 percent. (Because many projects address more than one audience, these percentages are estimates.) The remaining funds support the education and outreach components of nanoscale science and engineering research centers; they also target these audiences but are not specifically broken down by audience type.

Q3. For the undergraduate projects and for the informal science education projects, approximately what percentage of funding is allocated to equipment or instrumentation acquisitions for each use?

A3. For projects funded through the Nanotechnology Undergraduate Education (NUE) in Engineering program, nearly half have included the purchase of scanning or atomic force microscopes over the past several years. These awards provide up to \$200,000 for college curriculum development over two years; on average, 20 percent of the project budget is devoted to the purchase of equipment or instrumentation. Informal science education awards, typically made for the development of exhibits, media, and programs, do not typically require funds for purchase of major equipment.

Questions submitted by Representative Vernon J. Ehlers

Q1. What research has been done on the learning and teaching of nanotechnology? Do we know how kids best learn this subject? Is high school nanotechnology curricula currently being developed and, if so, by whom?

A1. Because the field is now and emerging, educational research studies are just beginning on the learning and teaching of nanotechnology. The NanoEd Resource Portal of the NSF-funded National Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT) [<http://www.nanoed.org/nlr/nlr.html>] identifies several such studies, such as the development of student's conceptions of size and using learning progressions to inform curriculum, instruction, and assessment design. These studies build on the existing literature on how students learn science and on educational research on learning of related topics, such as the atomic nature of matter.

Development of coherent high school nanotechnology curricula is also beginning under several NSF grants. For example, *NanoLeap* (Mid-Continent Regional Edu-

cational Laboratory) is creating and testing two month-long units in nanoscience to be used as replacement units in high school physics and chemistry courses. NanoSense (SRI International) is creating, testing, and disseminating a larger number of shorter curriculum units. Because they follow research and development methodologies, these projects are helping to build the knowledge base about effective learning and teaching along with creating instructional materials.

Q2. What other models exist in other disciplines (pharmacology, physics, chemistry, etc.) for continuous federal support of lab equipment? Along the same lines, if H.R. 2436 singles out nanotechnology, will this create tension between the disciplines/employers of other high tech industries?

A2. I am not generally aware of models for federal support of lab equipment other than its acquisition as part of research or education grants. It is possible that singling out nanotechnology might create tension, but I have no specific knowledge in this area.

Q3. What existing NSF programs can already fund this type of nanotechnology equipment?

A3. As noted, the Nanotechnology Undergraduate Education (NUE) program funds the purchase of this type of equipment as part of college course development. The Advanced Technology Education (ATE) program funds equipment or instrumentation for technician education at the two-year college level. Equipment also can be funded through the NSF Major Research Instrumentation (MRI) Program, which is designed to increase access to scientific and engineering equipment for research and research training in organizations of higher education, research museums, and non-profit research organizations. In addition, the EPSCoR Research Infrastructure Improvement Grant Program (RII) supports the acquisition of equipment for research and other discovery-based learning activities at predominately undergraduate and minority serving institutions.

Q4. You state in your testimony that “widely used and tested nanoscale science and engineering curricula do not yet exist, and it is difficult to add new content to existing overcrowded curricula, State standards, assessments, and textbooks.” That being the case, is there any research being done to tell us if there is even a need for this, particularly at the high school level?

A4. The following arguments based on professional judgment and expertise can be made for nanotechnology education at the college and high school level. One is the need for a future workforce, which will require trained scientists, engineers, and technicians capable of working in the field; nanotechnology education at both these levels could add to the pipeline. Another is that current and future nanotechnology applications offer topics of relevance to the study of STEM that could make it more engaging to students. A third is that the intrinsically interdisciplinary nature of nanotechnology could provide a more effective approach for students to learn STEM content. Given the early stage of development of the field and of nanotechnology education, there is not enough evidence at this point to support or counter these arguments.

Questions submitted by Representative Daniel Lipinski

Q1. Many of you testified that American students at all levels and the public in general must have a significant understanding of nanotechnology if America is to stay ahead in this field. Is this field different from other emerging scientific areas, either past or present, in a way that makes such widespread knowledge vital for the continued success of American endeavors in this area?

A1. Nanotechnology differs from many other STEM areas in its highly interdisciplinary and integrative nature, since the field brings together aspects of physics, chemistry, biology, materials science, environmental sciences, engineering, and medicine. In addition, large workforce needs have been projected, and the emerging applications of nanotechnology may have significant impact on people's lives and society. Therefore, one can argue that students and the public should have an awareness and basic understanding of the field and its applications and implications.

Q2. Dr. Fraser indicated in his testimony that university faculty have almost no access to funding support to assist in the development of undergraduate courses that would be coupled with lab experiences. Dr. Ucko, do the NSF programs for nanotechnology education at the undergraduate level support the types of activities described by Dr. Fraser and how widely available are they to college and university faculty?

A2. Yes, NSF provides funding for the development of undergraduate courses that can be coupled with lab experience. The Nanotechnology Undergraduate Education (NUE) in Engineering program funds course development in this area; it emphasizes new approaches to undergraduate engineering education through interdisciplinary collaborations. NUE in Engineering proposals must be submitted by U.S. universities and two- and four-year colleges (including community colleges) located and accredited in the U.S. that have a College/Department of Engineering or Engineering Technology with undergraduate programs in disciplines usually supported by NSF. Projects may be proposed by individual investigators or by groups from a College/Department of Engineering or Engineering Technology. In addition, the Division of Undergraduate Education offers another program that addresses this need more broadly, such as the Course, Curriculum, and Laboratory Improvement (CCLI) program. This program is open to all organizations that can apply for NSF funding, including colleges and universities.

Questions submitted by Representative Ralph M. Hall

Q1. Does NSF currently make any grants directly to secondary schools? If not, why not?

A1. Yes, NSF has made, and continues to make, grants directly to secondary schools and school districts, based on the merit review of proposals submitted to programs such as Information Technology Experiences for Students and Teachers (ITEST). In addition, secondary school teachers are extensively involved in many awards made to other organizations, such as universities, including nanotechnology education awards that focus on instructional materials and professional development.

Q2. You mention in your testimony that the University of Michigan “has assembled the most significant and developmentally appropriate learning goals in nanoscience for grade 7–12 learners.” Can you elaborate?

A2. NSF funded “A Workshop to Identify and Clarify Nanoscale Learning Goals” (University of Michigan, PI Joseph Krajcik) to create learning goals for grades 7–12. The three-day workshop held at SRI International in Palo Alto, Calif., on June 14–16, 2006 identified key nanoscience learning goals, which the PI and his team have developed into a manuscript, “The Big Ideas of Nanoscience.” This report has been widely circulated, discussed, and refined in the nanoscience education community, and is scheduled to be published by the National Science Teachers Association. “Big Ideas” identified in a recent draft of the report include the following:

- *Size and Scale.* Factors relating to size and scale help describe matter and predict its behavior.
- *Structure of Matter.* All matter is composed of atoms in constant motion. Atoms interact to form molecules or nanoscale structures interacting with each other to form nanoscale assemblies. The arrangement of the building blocks gives matter its properties.
- *Size-dependent Properties.* The properties of matter can change with scale. As the size of a material approaches the nanoscale, it often exhibits unexpected properties that lead to new functionality.
- *Forces.* All interactions can be described by multiple types of forces. On the nanoscale, electrical forces with varying strength tend to dominate interactions.
- *Self-Assembly.* Some materials can spontaneously assemble into organized structures. The process provides a useful way to manipulate matter at the nanoscale.
- *Tools and Instrumentation.* Development of new tools and instruments drives scientific progress. Recent development of specialized tools has led to new understanding of matter by helping scientists detect, manipulate, isolate, measure, fabricate, and investigate nanoscale matter.
- *Models and Simulations.* Because they are too small to see, models are needed to understand, visualize, predict, explain, and interpret data about nanoscale phenomena.
- *Nano and Society.* The field of nanotechnology is driven by the aim to advance broad societal goals. The products of nanotechnology may impact our lives in both positive and negative ways.
- *Quantum Mechanics.* As the size or mass of an object becomes smaller, the wave character becomes more important and quantum mechanics becomes necessary to explain its behavior.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Nivedita M. Ganguly, Chairperson, Science Department, Oak Ridge High School, Oak Ridge, TN

Questions submitted by Representative Vernon J. Ehlers

Q1. What research has been done on the learning and teaching of nanotechnology? Do we know how kids best learn this subject? Is high school nanotechnology curricula currently being developed and, if so, by whom?

A1. Students agree almost unanimously that when they have done inquiry-based labs with a variety of tools in a nanoscale it “has changed their view of the sciences and scientists.” They also said that “this was the best experience that they had ever had in a science class and they hoped that one day all high school students would have the opportunity to have the same experiences.” (Orange High School, North Carolina)

There are a number of different sources of Nanotechnology Curricula

- USA Nanotechnology Initiative has set up a nanotechnology website for K–12 students. A Teacher’s Guide has also been written.
- Nanaoscale Science is also in the process of developing Teaching Modules.
- National Center for Learning and Teaching in Nanoscale Science (NCLT) at Northwestern University.

These are just two examples of a number of different sources.

Q2. What other models exist in other disciplines (pharmacology, physics, chemistry, etc.) for continuous federal support of lab equipment? Along the same lines, if H.R. 2436 singles out nanotechnology, will this create tension between the disciplines/employers of other high tech industries?

A2. There is not a continuous support of federal funds for lab equipment. The way that we have been able to get them is through grants from different agencies—National Science Foundation, Bioteach Grants (started in Massachusetts, now slowly extending to other states). Teachers write grants to equip their labs and through professional development they are trained in their usage.

There will be no tension among the departments because nanotechnology is a very specific tool which will be applicable to every discipline.

Questions submitted by Representative Daniel Lipinski

Q1. Many of you testified that American students at all levels and the public in general must have a significant understanding of nanotechnology if America is to stay ahead in this field. Is this field different from other emerging scientific areas, either past or present, in a way that makes such widespread knowledge vital for the continued success of American endeavors in this area?

A1. Because nanotechnology can be linked to a variety of applications, we can help students of all ages understand how nanotechnology concepts are relevant to their everyday lives. This relevance will get them more excited about learning science and math. And because it integrates many disciplines (chemistry, physics, biology, environmental science, engineering etc.), it can build a strong interdisciplinary science literacy, which is absolutely imperative in today’s world.

Q2. What broader STEM education goals could exposure to nanotechnology in high school help achieve?

A2. The reason why exposure to nanotechnology would help STEM education is related to question 1—since it is a tool that underlies all the sciences, it is a way to be kinesthetically, learn trouble-shooting skills, and most importantly it will relate to their lives, they will be more engaged and hence more likely to remain in the fields of science and math. The number of students going into these areas is steadily decreasing and we have to find ways to stop that.

Q3. In your interactions with other science teachers and department Chairs across the country, do you sense that they want to push their students further and keep them on the cutting edge, or are they simply worried about teaching the basics?

A3. As a National Leader for the College Board I get a chance to travel all over the country. So , I get a chance to meet and talk to a lot of teachers and administrators. We all agree that the basics have to be taught. But, it should not stop there.

To be competitive in the world arena we have to make sure that our students are the cutting edge in their learning. World wide there will be a need for two million nano workers and we have to make sure that our students are part of the \$2 trillion nanotechnology market.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Hamish L. Fraser, Ohio Regents Eminent Scholar and Professor, Department of Materials Science and Engineering, Ohio State University

Questions submitted by Chairman Brian Baird

Q1. There is ongoing tension at the undergraduate level between providing a strong disciplinary education as a foundation for almost any STEM related academic or professional career, versus offering broad, interdisciplinary undergraduate programs. Nanotechnology clearly falls in the middle of that debate. Can you elaborate on whether you are advocating individual courses in nanotechnology or whether you would support the concept of a B.S. in nanotechnology, and if so, what that might look like?

A1. I am not a strong advocate of the immediate establishment of a B.S. in nanotechnology. I believe that nanotechnology impacts a large number of courses that are presently taught and so faculty have the opportunity to modify these existing classes to include relevant aspects of nanotechnology. Of course, faculty will also establish new courses with nanotechnology as the subject matter. As the number of these modified and new courses grow, I would expect, and support, the notion of a degree in a traditional area with specialization in nanotechnology (for example, similar to our materials science and engineering degrees with specializations in metals, ceramics, or polymers, etc.).

Q2. You mentioned in your testimony working with Columbus City schools to expose high school students to scanning electron microscopes. How did this partnership begin and how is it funded?

A2. The interaction with the Columbus City Schools began as an educational outreach activity of our Center for the Accelerated Maturation of Materials (CAMM). We made contact with a number of school districts, including Columbus, and found students from the Columbus Alternative High School to be very eager to become interns for one day per week. In this way, our outreach program was initiated and we have been working in this mode for several years. I have no specific source of funding for this activity and so make use of discretionary funds that are generated by some of the activities of CAMM.

Q3. Is this type of nanotechnology equipment aligned with the curricula currently in place? What prevents high schools from purchasing this equipment now?

A3. The equipment is now available, at a cost of ~\$60k per microscope. We have not yet aligned the use of the equipment with current high school curricula. We have been working with our high school interns to ascertain what sort of projects on the microscope are feasible and which will stimulate the imagination of students. It is our intention to collaborate with high school teachers to effect the inclusion of the instruments in their instructional materials. It is the cost of the instruments that prevents high schools from acquiring the microscopes.

Questions submitted by Representative Vernon J. Ehlers

Q1. Can you please explain how a course on nanotechnology differs from materials science? Instrumental analysis? Characterization? Is your goal to supply such equipment to majors and non-majors alike? If just majors, are these students already exposed to this type of equipment in their junior and senior years?

A1. In principle, a course on nanomaterials would be somewhat similar to a course on materials science. There would be an emphasis on understanding the role of scale, i.e., nanoscale, on the behavior and properties of these types of materials. I would not advocate establishing courses on instrument analysis or characterization specifically for nanotechnology, as the present courses cover the relevant material well.

I assume that your question refers to majors in materials science. It is my experience that juniors and seniors are exposed to materials characterization techniques, but their "hands-on" experience is rather limited. I am an advocate of including use of these recently developed and simplified instruments in a number of existing courses to assist in familiarizing students with characterization.

Questions submitted by Representative Daniel Lipinski

Q1. Many of you testified that American students at all levels and the public in general must have a significant understanding of nanotechnology if America is to stay ahead in this field. Is this field different from other emerging scientific areas, either past or present, in a way that makes such widespread knowledge vital for the continued success of American endeavors in this area?

A1. I believe that nanotechnology is rather different from other recent technologies which have been the subject of national and international focus. The reason is that nanotechnology impacts a very broad set of disciplines, for example, physical sciences and engineering, medical and bio-sciences, environmental sciences, food sciences, etc. It is because of this very broad impact that in the future this technology will have a very major influence on the Nation's economy. In contrast, take for example high temperature superconductivity. The scientific underpinning of this very important technological area is centered in solid state physics and so, from an educational viewpoint, the scientific impact is rather narrow.

The requirement for widespread knowledge in the case of nanotechnology arises from the need to develop a workforce that will be sufficiently equipped to permit exploitation of the economic advantages that nanotechnology will offer.

Q2. You indicated in your testimony that university faculty have almost no access to funding support to assist in the development of undergraduate courses that would be coupled with lab experiences. Were you aware of the NSF-funded undergraduate programs described by Dr. Ucko?

A2. I am aware of the funding opportunities currently offered by NSF. It has been my experience that faculty apply for instruments which may be used both for research and instruction. In this case, the complexity of the operation of the equipment limits its useful application in the classroom. The proposed bill is focused on education, involving acquisition of simplified instruments and the development of education modules that will increase the "hands-on" time for students.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Ray Vandiver, Vice President of New Project Development, Oregon Museum of Science and Industry

Question submitted by Representative Daniel Lipinski

Q1. Many of you testified that American students at all levels and the public in general must have a significant understanding of nanotechnology if America is to stay ahead in this field. Is this field different from other emerging scientific areas, either past or present, in a way that makes such widespread knowledge vital for the continued success of American endeavors in this area?

A1. Nanotechnology has been described as the convergence of physics, chemistry, and biology. The study and use of nanotechnology covers a broad range of disciplines and industries and can be thought of as its own area of science focus. It is more comparable to the field of chemistry or physics rather than a specific area of study such as genetic engineering or particle physics.

Nanotechnology is projected to have large impacts on the economy, the environment, and on quality of life. It will likely become embedded or play a significant factor in many of the products and procedures that will influence our lives and future. It is important for the general public to have context and confidence in this emerging field as it will have direct impact on them.

Questions submitted by Representative Ralph M. Hall

Q1. You testified that professional development funding is rare, incredibly valuable, and in great need to the informal science community, yet the bill before us today limits funding for this to 25 percent of the grant amount. Is this sufficient? Would you purchase nanotechnology equipment for your museum patrons to use? How many people do you estimate would use the equipment each year?

A1. Twenty-five percent of the grant amount could cover either the development of or the delivery of facilitated instruction and workshops for the professional development of museum educators. The amount would not be sufficient to cover both development and delivery. OMSI is always striving to provide direct access and experience to our visitors with exhibits and props that communicate cutting edge and emerging science and technology topics. We would be interested in purchasing exhibits and equipment that are designed specifically for use in the hands-on setting of a science museum. OMSI receives on average 750,000 visitors annually to our facility. Of that number, any one exhibit or lab experience will typically be experienced by 10 percent of the total. Based on this estimate, we would expect 75,000 people annually to be impacted by an exhibit or program on nanotechnology.

ANSWERS TO POST-HEARING QUESTIONS

Submitted to Sean Murdock, Executive Director, NanoBusiness Alliance

These questions were submitted to the witness, but were not responded to by the time of publication.

Questions submitted by Representative Daniel Lipinski

- Q1. Many of you testified that American students at all levels and the public in general must have a significant understanding of nanotechnology if America is to stay ahead in this field. Is this field different from other emerging scientific areas, either past or present, in a way that makes such widespread knowledge vital for the continued success of American endeavors in this area?*
- Q2. What is the nanobusiness community's chief concern relating to STEM education?*
- Q3. Are nanotechnology businesses currently able to hire enough qualified people? Can you predict a future trend? What is the impact of the high level of reliance on foreign students in American graduate science programs?*
- Q4. After the Sputnik launch 50 years ago this Thursday, we passed the National Defense Education Act to jump-start our nation's ability to generate aerospace scientists and engineers. There may not be a nano-Sputnik right now to focus our attention, but are we in danger of falling behind in nanotechnology? Specifically, are we going to be in trouble as we try to move beyond academic research to applications?*
- Q5. Technical education is undervalued in America, but I believe it is only going to become more important in the future. Recognizing that we are very early in the process of commercializing nanotechnology, what skills do you think will be required by nanotechnology businesses as they scale up and hire not just scientists and researchers, but technicians?*

Questions submitted by Representative Ralph M. Hall

- Q1. What is the average cost of the nanotechnology equipment your members wish to have the government purchase? What are the maintenance costs? What is the useful life of the equipment?*
- Q2. Are your members currently working on nanoscience education curricula? If so, are they collaborating with anyone on this effort and what type of research has been completed to help develop these curricula? Are you working with school districts to gauge where they are in being prepared to utilize this equipment?*

ANSWERS TO POST-HEARING QUESTIONS

Responses by Gerald Wheeler, Executive Director, National Science Teachers' Association

Q1. What research has been done on the learning and teaching of nanotechnology?

A1. One of the goals of the National Nanotechnology Initiative (NNI), a long-term research and development program, is to educate and train "a new generation of skilled workers in the multi-disciplinary perspectives necessary for rapid progress in nanotechnology." To support these educational goals, the National Science Foundation has funded several groups, including Nanoscale Science Engineering Centers (NSECs), Materials Research Science and Engineering Center (MRSECs), National Nanotechnology Infrastructure Network sites (NNIN), Nanoscale Informal Science Education network (NISE), and the National Center for Learning and Teaching Nanoscale Science and Engineering (NCLT), and Nanoscience Instructional Materials Development (NIMS) projects to create materials to inform the public (and then students) about nanoscience.

Q2. Do we know how kids best learn this subject?

A2. In an upcoming publication from the National Science Teachers Association titled "*The Big Ideas of Nanoscience*," authors Shawn Stevens, LeeAnn Sutherland, and Joseph Krajcik from the University of Michigan Ann Arbor, and Patricia Schank, from SRI International, discuss this issue.

Much more work is needed to determine how children can best learn this subject. According to the authors, we first need to "clarify the significant and developmentally appropriate learning goals in nanoscience for grade 7–16 learners. For nanoscience ideas to be used in schools, they need to be a component of the recognized learning goals for the Nation's youth."

"Because this is such a new field, debate exists about what should be included under the nanoscience and nanotechnology umbrella—the only agreement being that 'very small things' are involved. Although nanoscale concepts may be addressed in particular fields and courses, education has yet to systematically address nanoscale concepts in an integrated, cross-disciplinary fashion. The basic physics of atoms and molecules, for example, is the foundation of all science; therefore, early emphasis on these concepts would likely prove beneficial for students as they study biology, chemistry, physics and Earth science. Building understanding in all of these disciplines from the atomic and molecular level can facilitate the interdisciplinary connections that students need to make to understand nanoscience and other emerging science. However, education traditionally presents concepts in a discipline-defined rather than cross-disciplinary manner."

"Incorporating any emerging scientific field into the classroom presents many challenges. As with any addition to the curriculum, new materials must be developed, and professional development must be implemented in order to prepare teachers to successfully support student learning. However, emerging science brings with it unique challenges and questions. Which topics are the most important? Which ones can and should be incorporated into the curriculum? At what grade level is it appropriate to introduce particular concepts? Where in the instructional sequence do concepts logically build on what came before and what will follow? How do new ideas connect to those already a part of the traditional science curriculum? How are these new topics prioritized relative to traditional science concepts? Determining the answers to these questions is a difficult and complex process that requires a coordinated effort between scientists, educators, researchers and policy-makers."

"Increasing the challenge for the educational community is the interdisciplinary nature of nanoscience, which sets it apart from the disciplines contained in a traditional grades 7–16 science curriculum. Science in American schools tends to be taught in disciplinary fashion, with emphasis on biology, chemistry or physics, rather than on concepts important across disciplines. Emphasis on cross-disciplinary concepts would arguably enable students to develop deeper conceptual understanding than is currently the case. The interdisciplinary nature of nanoscience (and other emerging science) necessitates erasure of the curricular demarcations traditionally supported in schools. As a model, science laboratories that are the source of major breakthroughs are often comprised of interdisciplinary teams (Ref). The learning goals associated with nanoscience must explicitly foster interdisciplinary connections as well as deeper understanding of fundamental, core concepts and principles."

"It is important to consider how the learning goals in nanoscience align with national standards. In the current educational climate, schools are under increasing pressure to show that their students can succeed on high-stakes examinations

aligned with Standards. But, without explicit links to the national, State or local standards, new scientific ideas are difficult to introduce into the curriculum.”

“Related to that is the question of how nanoscience is introduced. It is imperative that nanoscience not be considered a “topic” in the curriculum, but must be integrated such that nanoscience concepts are brought to the fore at appropriate points within the curriculum. In the past, emerging science topics were often taught as separate entities, and the links between traditional science ideas and new ones were not emphasized (i.e., newer topics are often taught in stand-alone units). Because they are not part of the formal curriculum, new ideas may not be well connected to traditional concepts either in their presentation or in terms of students’ conceptual development, even though connections can illuminate the process of science for students as well as provide a motivation for them to learn science.”

“It seems clear that a better strategy would be to carefully and systematically integrate new scientific ideas into the curriculum, making it more interdisciplinary in the process. Connections between nanoscience and traditional mathematics and science must be explicit for students. These connections should be made not just within a single class, but across grades. In order to achieve this, materials must be developed that support learning core principles, while also aligning with the national, State and local standards. However, as the nanotechnology revolution was in its infancy when the Benchmarks (AAAS, 1993) and Standards (NRC, 1996) were written, many concepts critical for understanding nanoscale science were not included or explicitly specified.”

“Therefore, the learning goals associated with nanoscience must explicitly foster the necessary interdisciplinary connections. Because these connections have not historically been fostered at either the secondary or post-secondary level, the teachers themselves may not have made them. Therefore, these connections must be made explicit to teachers through professional development and curriculum materials.”

“Having a set of agreed upon learning goals for nanoscience will help ensure that all components of the educational system including curriculum, instruction, and assessment can be aligned. Alignment occurs once learning goals are clearly defined, specified, and developed. Learning goals drive state assessments that, in turn drive materials, resources and teacher education. Identifying appropriate nanoscience learning goals will allow the development of aligned science education that will provide students with the ability to explain phenomena within and between disciplines (Wilson & Berenthal, 2006). Aligning all parts of the system to learning goals fosters the development of instructional tools and resources, educational experiences for teachers, research studies, and policies that are focused on these same critical ends.”

Q3. Is high school nanotechnology curricula being developed and, if so, by whom?

A3. The *NanoLeap* project is developing instructional materials that teach high school students about nanoscale science. The curriculum modules, entitled *A NANO LEAP INTO NEW SCIENCE*, will include student activities, experiments, and assessments for use as replacement units in high school physical science and chemistry courses. The materials will promote student learning of the interdisciplinary nanoscale core concepts of force (physics) as it relates to properties of matter (chemistry), scale (mathematics), scientific instrumentation (technology), and processes (inquiry). Teacher guides and professional development opportunities will address the varied needs of the science education community and ensure effective classroom implementation. This work is supported by the National Science Foundation, Division of Elementary, Secondary and Informal Education award #ESI-0426401.

SRI International, an independent research and development organization, received a four-year, \$925,000 grant from the National Science Foundation to help high school students visualize the principles of nanoscience and nanotechnology—the physical, chemical, and biological behavior of particles on a nanoscopic scale. SRI’s program, *NanoSense*, brings an interdisciplinary approach to viewing core concepts from physics, chemistry, biology, materials science and engineering through a different lens. The *NanoSense* curriculum will include classroom-tested activities to help high school students understand the underlying principles, applications and implications of nanoscale science. Some of the activities will be simple, one-day enrichment activities, and others will span several class periods.

These activities will be conducted in science-related classrooms at five high schools prior to national dissemination. Teachers will work with the *NanoSense* team to advise on activity development and conduct pilot tests. A few hundred students are expected to engage in program activities.

During the program, SRI researchers will study how students improve their understanding of nanoscience concepts and technological applications over time, and

how teachers use the NanoSense tools and activities to support student discourse and understanding.

NanoSense builds on *ChemSense*, an NSF-funded SRI program to study students' understanding of chemistry and develop software and curriculum to help students investigate chemical systems and express their ideas in animated chemical notation. SRI is working closely with chemists, physicists, educators and nanoscientists to generate nanoscience activities that build on ChemSense activities.

The NSF funded Center for Learning and Teaching in Nanoscale Science and Engineering (NCLT), under the direction of Northwestern Professor of Materials Science and Engineering, Robert P.H. Chang, will develop scientist-educators who can introduce nanoscience and nanoengineering concepts into schools and undergraduate classrooms. Additionally, it will play the key role in a national network of researchers and educators committed to ensuring that all Americans are academically prepared to participate in the new opportunities nanotechnology will offer.

The NCLT is a partnership between Northwestern University, Purdue University, the University of Michigan, Argonne National Laboratories, and the Universities of Illinois at Chicago and Urbana-Champaign. Drawing on the strengths of the various partners in nanotechnology, instruction-materials development, educational assessment, and student cognition, *the NCLT will create modular education materials designed to integrate with existing curricula in grades 7–12*, and to align with national and state science education standards. Each module will be based on topics from nanoscience and nanoengineering, selected and developed by an interdisciplinary team including scientists, engineers, education researchers and graduate students, and practicing teachers. Expanded versions of the modules will be targeted at community colleges and undergraduate institutions and will eventually serve as the core of semester-long courses in nanotechnology.

Exploring the Nanoworld website, an offering of the University of Wisconsin–Madison Materials Research Science and Engineering Center (MRSEC) Interdisciplinary Education Group (IEG), is an excellent resource for teachers and students of all ages. Available on the site are movies, slide shows, kits and references (including the Lego® nanobricks booklet), and modules for K–12 teachers. See also UW's Educator Resources page from the Internships in Public Science Education program.

Northwestern University's Materials World Modules. This center has produced a series of interdisciplinary modules based on topics in materials science, including composites, ceramics, concrete, biosensors, biodegradable materials, smart sensors, polymers, food packaging, and sports materials. The modules are designed for use in middle and high school science, technology, and math classes and have been used by over 9,000 students in schools nationwide.

Nanotechnology Education Kits, experiential learning materials for middle and high school students, are available from NanoSonic, Blacksburg, Va. See also Nanoscience Education online.

Nanoscale Science Education Center at University of North Carolina–Chapel Hill, shows middle and high school students how an atomic force microscope works and features experiments on live viruses. One of their partners is the Nanoscale Science Education Group at North Carolina State University's College of Education.

Penn State University's Center for Nanotechnology Education and Utilization offers resources such as Workshops for Educators and a video about "Careers in Nanofabrication" that you can view online or order a free copy. High school students from across Pennsylvania can attend a three-day summer "Nanotech Camp." These nanotech camps provide secondary school students with an orientation to basic nanofabrication processes and applications, and the opportunity to observe these same nanofabrication processes in the Penn State Nanofabrication Facility.

The *Nanotechnology Simulation Hub* centered at Purdue University has online experiences in nanotechnology available.

The *Nanobiotechnology Center* located at Cornell University has special Teacher Resources, including online lesson plans for K–12 student activities and information about Montessori curriculum development.

NanoKids™, is a project of Rice University's Tour Group. An overview of the program is online.

Interactive Nano-visualization in Science and Engineering Education (IN-VSEE) is a consortium of university and industry scientists and engineers, community college and high school science faculty and museum educators with a common vision of creating an interactive web site to develop a new educational thrust based on remote operation of advanced microscopes and nano-fabrication tools coupled to powerful surface characterization methods.

NANOPOLIS™ offers intuitive multimedia educational material on nanotechnology, a result of the collaboration with more than 200 research groups worldwide.

New programs to promote, educate and excite young people about the amazing world of nanotechnology are being designed under a partnership between the *NanoBusiness Alliance* and the *National Science & Technology Education Partnership* (NSTEP).

Q4. Is this type of nanotechnology equipment aligned with the curricula currently in place?

A4. We know of no research that has determined if this type of nanotechnology equipment is aligned with current curriculum.

Q5. What prevents high schools from purchasing this equipment now?

A5. A lack of funding prevents high schools from purchasing this equipment. According to the *2000 National Survey of Science and Mathematics Education*, an NSF-funded project conducted by Horizon Research, the median amount high schools spent per year on science equipment was \$1,000. The median amount high schools spent per year on consumable supplies was \$1,500, and the median amount high schools spent per year on software was \$100. Broken down on a per pupil basis:

- \$2.05 was the median amount high schools spent per pupil on science equipment
- \$3.12 was the median amount high schools spent per pupil on consumable supplies
- \$0.19 was the median amount high schools spent per pupil on software.

Q6. Many of you testified that American students at all levels and the public in general must have a significant understanding of nanotechnology if America is to stay ahead in this field. Is this field different from other emerging scientific areas, either past or present, in a way that makes such widespread knowledge vital for the continued success of American endeavors in this area?

A6. While we believe that nanotechnology is an emerging important research area and employment opportunity, it is difficult to see how this is different from microbiology and global climate change, to mention just two examples. What our nation's children need is a solid foundation in the fundamental aspects of science that are the precursors of success in any of the emerging 21st century technologies.

Q7. Your testimony has focused on the need to address fundamental problems in our science classroom—the need to bring up the trailing edge of our nation's science education infrastructure. But should we not at the same time push forward the leading edge, by giving good schools the opportunity to teach their capable students 21st century science?

A7. Yes, we need to address both “ends of the spectrum” (as well as the middle). In the 21st century our nation needs to invest its limited resources in areas that will have the largest impact. The fundamental problems in our nation's science classrooms (specifically the science laboratory experiences) is not confined to just cohort of students. As stated in the National Research Council's report, *America's Lab Report*, our nation's science education laboratories are in dire shape with researchers and educators not even agreeing on how to define high school science laboratories or on their purposes.

Appendix 2:

ADDITIONAL MATERIAL FOR THE RECORD

110TH CONGRESS
1ST SESSION

H. R. 2406

To authorize the National Institute of Standards and Technology to increase its efforts in support of the integration of the healthcare information enterprise in the United States.

IN THE HOUSE OF REPRESENTATIVES

MAY 21, 2007

Mr. GORDON of Tennessee introduced the following bill; which was referred to the Committee on Science and Technology

A BILL

To authorize the National Institute of Standards and Technology to increase its efforts in support of the integration of the healthcare information enterprise in the United States.

1 *Be it enacted by the Senate and House of Representa-*
2 *tives of the United States of America in Congress assembled,*

3 SECTION 1. FINDINGS.

4 Congress finds the following:

5 (1) The National Institute of Standards and
6 Technology, because of the electronic commerce, in-
7 formation technology, security, and privacy expertise
8 in its laboratories and the healthcare component of

1 the Malcolm Baldrige National Quality Award, and
2 its long history of working with the information
3 technology and healthcare industries, is well
4 equipped to address the technical challenges posed
5 by healthcare information enterprise integration.

6 (2) Therefore, it is in the national interest for
7 the National Institute of Standards and Technology
8 to accelerate its efforts—

9 (A) to develop standards, standards con-
10 formance tests, and enterprise integration proc-
11 esses that are necessary to increase efficiency
12 and quality of care, and lower costs in the
13 healthcare industry; and

14 (B) ensuring that all components of the
15 United States healthcare infrastructure can be
16 a part of an electronic information network that
17 is reliable, interoperable, and secure, and pro-
18 tects privacy.

19 **SEC. 2. HEALTHCARE INFORMATION ENTERPRISE INTE-**
20 **GRATION INITIATIVE.**

21 (a) ESTABLISHMENT.—The Director of the National
22 Institute of Standards and Technology shall establish an
23 initiative for advancing healthcare information enterprise
24 integration within the United States. In carrying out this
25 section, the Director shall involve various units of the Na-

1 tional Institute of Standards and Technology, including its
2 laboratories and the Malcolm Baldrige National Quality
3 Program. This initiative shall build upon ongoing efforts
4 of the National Institute of Standards and Technology,
5 the private sector, and other Federal agencies, shall in-
6 volve consortia that include government and industry, and
7 shall be designed to permit healthcare information enter-
8 prise integration.

9 (b) TECHNICAL ACTIVITIES.—In order to carry out
10 this section, the Director may focus on—

- 11 (1) information technology standards and inter-
12 operability analysis, which may include the develop-
13 ment of technical testbeds;
- 14 (2) software conformance and certification;
- 15 (3) security and privacy;
- 16 (4) medical device communication;
- 17 (5) supporting the provisioning of technical ar-
18 chitecture products for management and retrieval;
- 19 (6) supporting the establishment of conform-
20 ance testing infrastructure;
- 21 (7) information management, including elec-
22 tronic health records management and data summa-
23 rization; and
- 24 (8) health information usability, access, and de-
25 cision support.

1 (c) OTHER ACTIVITIES.—The Director may assist
2 healthcare representatives and organizations and Federal
3 agencies in the development of technical roadmaps that
4 identify the remaining steps needed to ensure that stand-
5 ards for application protocols, interoperability, data integ-
6 rity, and security and privacy, as well as the corollary con-
7 formance test protocols, will be in place. These roadmaps
8 shall rely upon voluntary consensus standards where pos-
9 sible.

10 (d) PLANS AND REPORTS.—Not later than 90 days
11 after the date of enactment of this Act, and annually
12 thereafter, the Director shall transmit a report to the
13 Committee on Science and Technology of the House of
14 Representatives and the Committee on Commerce,
15 Science, and Transportation of the Senate on the activities
16 of the National Institute of Standards and Technology
17 under this section.

18 **SEC. 3. FEDERAL HEALTHCARE INFORMATION TECH-**
19 **NOLOGY SYSTEMS AND INFRASTRUCTURE.**

20 (a) GUIDELINES AND STANDARDS.—Not later than
21 6 months after the date of enactment of this Act, the Di-
22 rector of the National Institute of Standards and Tech-
23 nology, in consultation with industry and appropriate Fed-
24 eral agencies, shall develop technology-neutral information
25 technology infrastructure guidelines and standards, or

1 adopt existing technology-neutral industry guidelines and
2 standards, for use by Federal agencies to enable those
3 agencies to effectively select and utilize healthcare infor-
4 mation technologies in a manner that is—

5 (1) sufficiently secure and provides adequate
6 privacy to meet the needs of those agencies, their
7 transaction partners, and the general public; and

8 (2) interoperable, to the maximum extent pos-
9 sible.

10 (b) ELEMENTS.—The guidelines and standards devel-
11 oped under subsection (a) shall—

12 (1) promote the use by Federal agencies of
13 commercially available products that incorporate the
14 guidelines and standards developed under subsection
15 (a);

16 (2) develop uniform testing procedures suitable
17 for determining the conformance of commercially
18 available and Federal healthcare information tech-
19 nology products with the guidelines and standards;

20 (3) support and promote the testing of elec-
21 tronic healthcare information technologies utilized by
22 Federal agencies;

23 (4) provide protection and privacy profiles;

1 (5) establish a core set of interoperability speci-
2 fications in transactions between Federal agencies
3 and their transaction partners; and

4 (6) include validation criteria to enable Federal
5 agencies to select healthcare information tech-
6 nologies appropriate to their needs.

7 (c) REPORTS.—Not later than 18 months after the
8 date of enactment of this Act, and annually thereafter,
9 the Director shall transmit to the Congress a report that
10 includes a description and analysis of—

11 (1) the level of interoperability, privacy, and se-
12 curity of technologies for sharing healthcare infor-
13 mation among Federal agencies; and

14 (2) the problems Federal agencies are having
15 with, and the progress such agencies are making to-
16 ward, ensuring interoperable, secure, and private
17 healthcare information systems and electronic
18 healthcare records.

19 (d) SENIOR INTERAGENCY COUNCIL ON FEDERAL
20 HEALTHCARE INFORMATION TECHNOLOGY INFRASTRUC-
21 TURE.—The Undersecretary of Commerce for Technology
22 shall establish a Senior Interagency Council on Federal
23 Healthcare Information Technology Infrastructure. The
24 responsibilities of the Council are to—

1 (1) coordinate the development and deployment
2 of healthcare information technology solutions across
3 all Federal departments and agencies, with emphasis
4 on interoperability, privacy, and security issues;

5 (2) coordinate the associated technology trans-
6 fer to and from the private sector; and

7 (3) coordinate Federal funding and participa-
8 tion in private, voluntary standards development or-
9 ganizations, as related to electronic healthcare
10 records systems.

11 **SEC. 4. RESEARCH AND DEVELOPMENT PROGRAMS.**

12 (a) HEALTHCARE INFORMATION ENTERPRISE INTE-
13 GRATION RESEARCH CENTERS.—

14 (1) IN GENERAL.—The Director of the National
15 Institute of Standards and Technology, in consulta-
16 tion the Director of the National Science Foundation
17 and other appropriate Federal agencies, shall estab-
18 lish a program of assistance to institutions of higher
19 education (or consortia thereof) that enter into part-
20 nerships with for-profit entities or nonprofit entities
21 to establish multidisciplinary Centers for Healthcare
22 Information Enterprise Integration. The partner-
23 ships may also include government laboratories.

1 (2) REVIEW; COMPETITION.—Grants shall be
2 awarded under this subsection on a merit-reviewed,
3 competitive basis.

4 (3) PURPOSE.—The purposes of the Centers
5 shall be—

6 (A) to generate innovative approaches to
7 healthcare information enterprise integration by
8 conducting cutting-edge, multidisciplinary re-
9 search on the systems challenges to healthcare
10 delivery; and

11 (B) the development and use of informa-
12 tion technologies and other complementary
13 fields.

14 (4) RESEARCH AREAS.—Research areas may in-
15 clude—

16 (A) the interfaces between human informa-
17 tion and communications technology systems;

18 (B) voice-recognition systems;

19 (C) software that improves interoperability
20 and connectivity among systems;

21 (D) software dependability in systems crit-
22 ical to healthcare delivery;

23 (E) measurement of the impact of informa-
24 tion technologies on the quality and productivity
25 of healthcare;

1 (F) healthcare information enterprise man-
2 agement; and

3 (G) information technology security and
4 integrity.

5 (5) APPLICATIONS.—An institution of higher
6 education (or a consortium thereof) seeking funding
7 under this subsection shall submit an application to
8 the Director at such time, in such manner, and con-
9 taining such information as the Director may re-
10 quire. The application shall include, at a minimum,
11 a description of—

12 (A) the research projects that will be un-
13 dertaken by the Center and the respective con-
14 tributions of the participating entities;

15 (B) how the Center will promote active col-
16 laboration among scientists and engineers from
17 different disciplines, such as information tech-
18 nology, biologic sciences, management, social
19 sciences, and other appropriate disciplines;

20 (C) technology transfer activities to dem-
21 onstrate and diffuse the research results, tech-
22 nologies, and knowledge; and

23 (D) how the Center will contribute to the
24 education and training of researchers and other

1 professionals in fields relevant to healthcare in-
2 formation enterprise integration.

3 (b) NATIONAL INFORMATION TECHNOLOGY RE-
4 SEARCH AND DEVELOPMENT PROGRAM.—The National
5 High-Performance Computing Program established by
6 section 101 of the High-Performance Computing Act of
7 1991 (15 U.S.C. 5511) shall coordinate Federal research
8 and development programs related to the development and
9 deployment of health information technology, including ac-
10 tivities related to—

- 11 (1) computer infrastructure;
- 12 (2) data privacy and security;
- 13 (3) development of large-scale, distributed, reli-
14 able computing systems;
- 15 (4) wired, wireless, and hybrid high-speed net-
16 working;
- 17 (5) development of software and software-inten-
18 sive systems;
- 19 (6) human-computer interaction and informa-
20 tion management technologies; and
- 21 (7) the social and economic implications of in-
22 formation technology.

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